AMIA
INFORMATICS PROFESSIONALS. LEADING THE WAY.

2A-2: Applied Decision Support

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Clinical Informatics
Board Review Course

Clinical Informatics Subspecialty Delineation of Practice (CIS DoP)

Domain 1: Fundamental Knowledge and Skills (no Tasks are associated with this Domain which is focused on fundamental knowledge and skills)

Clinical Informatics

K001. The discipline of informatics (e.g., definitions, history, careers, professional organizations)
K002. Fundamental informatics concepts, models, and theories
K003. Core clinical informatics literature (e.g., foundational literature, principle journals, critical analysis of literature, use of evidence to inform practice)
K004. Descriptive and inferential statistics
K005. Health Information Technology (HIT) principles and science
K006. Computer programming fundamentals and computational thinking
K007. Basic systems and network architectures
K008. Basic database structure, data retrieval and analytics techniques and tools
K009. Development and use of interoperability/exchange standards (e.g., Fast Health Interoperability Resources [FHIR], Digital Imaging and Communications in Medicine [DICOM])
K010. Development and use of transaction standards (e.g., American National Standards Institute X12)
K011. Development and use of messaging standards (e.g., Health Level Seven [HL7] v2)
K012. Development and use of ancillary data standards (e.g., imaging and Laboratory Information System[LIS])
K013. Development and use of data model standards
K014. Vocabularies, terminologies, and nomenclatures (e.g., Logical Observation Identifiers Names and Codes [LOINC], Systematized Nomenclature of Medicine --Clinical Terms [SNOMED-CT], RxNorm, International Classification Of Diseases[ICD], Current Procedural Terminology [CPT])
K015. Data taxonomies and ontologies
K016. Security, privacy, and confidentiality requirements and practices
K017. Legal and regulatory issues related to clinical data and information sharing
K018. Technical and non-technical approaches and barriers to interoperability
K019. Ethics and professionalism

The Health System

K020. Primary domains of health, organizational structures, cultures, and processes (e.g., health care delivery, public health, personal health, population health, education of health professionals, clinical research)
K021. Determinants of individual and population health
K022. Forces shaping health care delivery and considerations regarding health care access
K023. Health economics and financing
K024. Policy and regulatory frameworks related to the healthcare system
K025. The flow of data, information, and knowledge within the health system

Domain 2: Improving Care Delivery and Outcomes

K026. Decision science (e.g., Bayes theorem, decision analysis, probability theory, utility and preference assessment, test characteristics)
K027. Clinical decision support standards and processes for development, implementation, evaluation, and maintenance
K028. Five Rights of clinical decision support (i.e., information, person, intervention formats, channel, and point/time in workflow)
K029. Legal, regulatory, and ethical issues regarding clinical decision support
K030. Methods of workflow analysis
K031. Principles of workflow re-engineering
K032. Quality improvement principles and practices (e.g., Six Sigma, Lean, Plan-Do-Study-Act [PDSA] cycle, root cause analysis)
K033. User-centered design principles (e.g., iterative design process)
K034. Usability testing
K035. Definitions of measures (e.g., quality performance, regulatory, pay for performance, public health surveillance)
K036. Measure development and evaluation processes and criteria
K037. Key performance indicators (KPIs)
K038. Claims analytics and benchmarks
K039. Predictive analytic techniques, indications, and limitations
K040. Clinical and financial benchmarking sources (e.g., Gartner, Healthcare Information and Management Systems Society [HIMSS] Analytics, Centers for Medicare and Medicaid Services [CMS], Leapfrog)
K041. Quality standards and measures promulgated by quality organizations (e.g., National Quality Forum [NQF], Centers for Medicare and Medicaid Services [CMS], National Committee for Quality Assurance [NCQA])
K042. Facility accreditation quality and safety standards (e.g., The Joint Commission, Clinical Laboratory Improvement Amendments [CLIA])
K043. Clinical quality standards (e.g., Physician Quality Reporting System [PQRS], Agency for Healthcare Research and Quality [AHRQ], National Surgical Quality Improvement Program [NSQIP], Quality Reporting Document Architecture [QRDA], Health Quality Measure Format [HQMF], Council on Quality and Leadership [CQL], Fast Health Interoperability Resources [FHIR] Clinical Reasoning)
K044. Reporting requirements
K045. Methods to measure and report organizational performance
K046. Adoption metrics (e.g., Electronic Medical Records Adoption Model [EMRAM], Adoption Model for Analytics Maturity [AMAM])
K047. Social determinants of health
K048. Use of patient-generated data
K049. Prediction models
K050. Risk stratification and adjustment
K051. Concepts and tools for care coordination
K052. Care delivery and payment models

Domain 3: Enterprise Information Systems

K053. Health information technology landscape (e.g., innovation strategies, emerging technologies)
K054. Institutional governance of clinical information systems
K055. Information system maintenance requirements
K056. Information needs analysis and information system selection
K057. Information system implementation procedures
K058. Information system evaluation techniques and methods
K059. Information system and integration testing techniques and methodologies
K060. Enterprise architecture (databases, storage, application, interface engine)
K061. Methods of communication between various software components
K062. Network communications infrastructure and protocols between information systems (e.g., Transmission Control Protocol/Internet Protocol [TCP/IP], switches, routers)
K063. Types of settings (e.g., labs, ambulatory, radiology, home) where various systems are used
K064. Clinical system functional requirements
K065. Models and theories of human-computer (machine) interaction (HCI)
K066. HCI evaluation, usability engineering and testing, study design and methods
K067. HCI design standards and design principles
K068. Functionalities of clinical information systems (e.g., Electronic Health Records [EHR], Laboratory Information System [LIS], Picture Archiving and Communication System [PACS], Radiology Information System [RIS] vendor-neutral archive, pharmacy, revenue cycle)
K069. Consumer-facing health informatics applications (e.g., patient portals, mobile health apps and devices, disease management, patient education, behavior modification)
K070. User types and roles, institutional policy and access control
K071. Clinical communication channels and best practices for use (e.g., secure messaging, closed loop communication)
K072. Security threat assessment methods and mitigation strategies
K073. Security standards and safeguards
K074. Clinical impact of scheduled and unscheduled system downtimes
K075. Information system failure modes and downtime mitigation strategies (e.g., replicated data centers, log shipping)
K076. Approaches to knowledge repositories and their implementation and maintenance
K077. Data storage options and their implications
K078. Clinical registries
K079. Health information exchanges
K080. Patient matching strategies
K081. Master patient index
K082. Data reconciliation
K083. Regulated medical devices (e.g., pumps, telemetry monitors) that may be integrated into information systems
K084. Non-regulated medical devices (e.g., consumer devices)
K085. Telehealth workflows and resources (e.g., software, hardware, staff)

Domain 4: Data Governance and Data Analytics

K086. Stewardship of data
K087. Regulations, organizations, and best practice related to data access and sharing agreements, data use, privacy, security, and portability
K088. Metadata and data dictionaries
K089. Data life cycle
K090. Transactional and reporting/research databases
K091. Techniques for the storage of disparate data types
K092. Techniques to extract, transform, and load data
K093. Data associated with workflow processes and clinical context
K094. Data management and validation techniques
K095. Standards related to storage and retrieval from specialized and emerging data sources
K096. Types and uses of specialized and emerging data sources (e.g., imaging, bioinformatics, internet of things (IoT), patient-generated, social determinants)
K097. Issues related to integrating emerging data sources into business and clinical decision making
K098. Information architecture
K099. Query tools and techniques
K100. Flat files, relational and non-relational/NoSQL database structures, distributed file systems
K101. Definitions and appropriate use of descriptive, diagnostic, predictive, and prescriptive analytics
K102. Analytic tools and techniques (e.g., Boolean, Bayesian, statistical/mathematical modeling)
K103. Advanced modeling and algorithms
K104. Artificial intelligence
K105. Machine learning (e.g., neural networks, support vector machines, Bayesian network)
K106. Data visualization (e.g., graphical, geospatial, 3D modeling, dashboards, heat maps)
K107. Natural language processing
K108. Precision medicine (customized treatment plans based on patient-specific data)
K109. Knowledge management and archiving science
K110. Methods for knowledge persistence and sharing
K111. Methods and standards for data sharing across systems (e.g., health information exchanges, public health reporting)

Domain 5: Leadership and Professionalism

K112. Environmental scanning and assessment methods and techniques
K113. Consensus building, collaboration, and conflict management
K114. Business plan development for informatics projects and activities (e.g., return on investment, business case analysis, pro forma projections)
K115. Basic revenue cycle
K116. Basic managerial/cost accounting principles and concepts
K117. Capital and operating budgeting
K118. Strategy formulation and evaluation
K119. Approaches to establishing Health Information Technology (HIT) mission and objectives
K120. Communication strategies, including one-on-one, presentation to groups, and asynchronous communication
K121. Effective communication programs to support and sustain systems implementation
K122. Writing effectively for various audiences and goals
K123. Negotiation strategies, methods, and techniques
K124. Conflict management strategies, methods, and techniques
K125. Change management principles, models, and methods
K126. Assessment of organizational culture and behavior change theories
K127. Theory and methods for promoting the adoption and effective use of clinical information systems
K128. Motivational strategies, methods, and techniques
K129. Basic principles and practices of project management
K130. Project management tools and techniques
K131. Leadership principles, models, and methods
K132. Intergenerational communication techniques
K133. Coaching, mentoring, championing and cheerleading methods
K134. Adult learning theories, methods, and techniques
K135. Teaching modalities for individuals and groups
K136. Methods to assess the effectiveness of training and competency development
K137. Principles, models, and methods for building and managing effective interdisciplinary teams
K138. Team productivity and effectiveness (e.g., articulating team goals, defining rules of operation, clarifying individual roles, team management, identifying and addressing challenges)
K139. Group management processes (e.g., nominal group, consensus mapping, Delphi method)

Knowledge Statements from the DoP

K027. Clinical decision support standards and processes for development, implementation, evaluation, and maintenance

K028. Five Rights of clinical decision support (i.e., information, person, intervention formats, channel, and point/time in workflow)

K076. Approaches to knowledge repositories and their implementation and maintenance

K109. Knowledge management and archiving science

K110. Methods for knowledge persistence and sharing

Key Topics

The difference between interruptive/modal and non-interruptive/modeless alerts

CDS intervention classifications

- by function (alerting, reminding, critiquing, etc)
- by area of clinical care (prevention, diagnosis, treatment, follow-up, care planning)
- by intended audience

The “five rights” and “10 commandments” of an effective CDS intervention.

Review of current state of CDS effectiveness

Common limitations of evaluations of CDS interventions and ways to overcome these limitations.

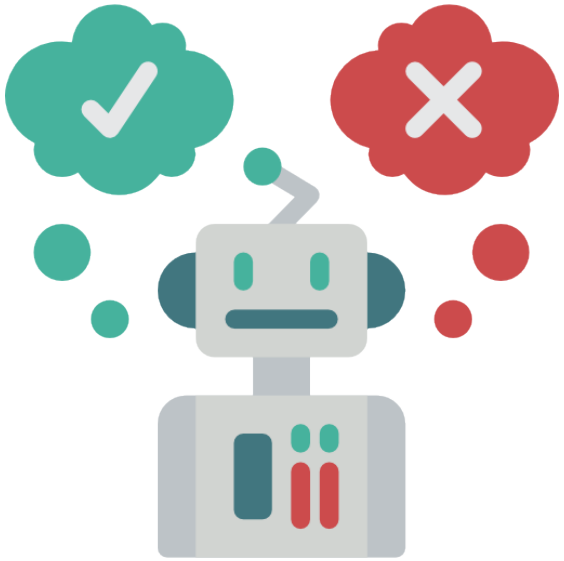
Facilitating broader adoption of CDS tools through interoperability, clinical terminology, and guideline representation standards

Common strategies for maintaining and updating decision support tools, and the risks of not having these strategies in place.

Approaches for guideline representation and sharing of CDS content

2A-2 Applied Decision Support

- Key Components
- Opportunities for Decision Support
- Modes of delivery
- Interruptiveness
- Implementations & Example Categories
- Advanced Applications
- Designing CDS: The 5 Rights
- Evaluation
- Knowledge Representation & Sharing



clipart credit: [illegible]

Definition of Clinical Decision Support

Most restrictive: an electronic system that provides structured guidance based on patient-specific inputs

- Expert systems
- Conditional alerts

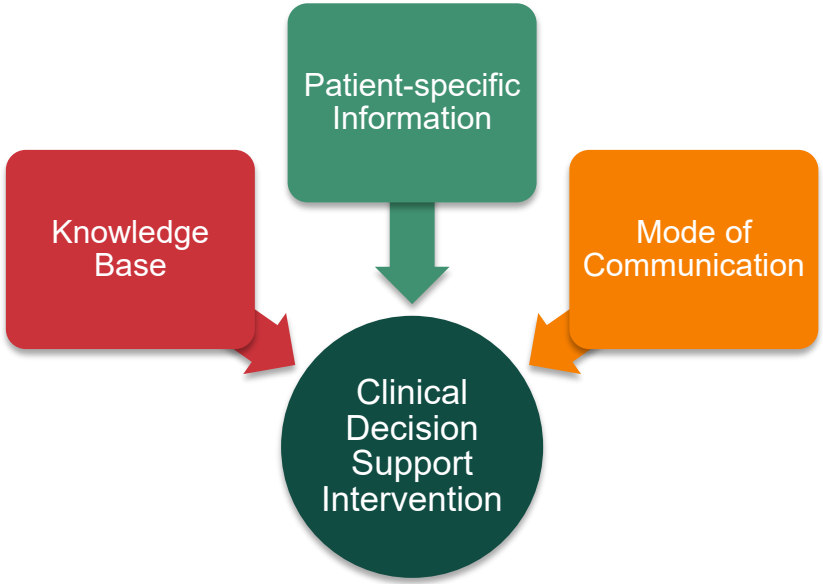
Less restrictive: any electronic tool that reduces the cognitive burden of patient care in an EHR

- Order sets & corollary orders
- Data visualization techniques, visual design standards

Least restrictive: “Not all decision support is electronic decision support”

clipart credit: [illegible]

The “Textbook” Definition



“Active knowledge systems which use two or more items of patient data to generate case-specific advice.” - Wyatt & Spiegenhalter, SCAMC 1991

clipart credit: [illegible]

Functions of CDS

Function	Example
Alerting	Highlighting out-of-range laboratory values
Reminding	Reminding the clinician to schedule a mammogram
Critiquing	Rejecting an electronic order
Interpreting	Interpreting the echocardiogram
Predicting	Predicting risk of mortality from a severity-of-illness score
Diagnosing	Listing a differential diagnosis for a patient with chest pain
Assisting	Tailoring the antibiotic choices for liver transplantation and renal failure
Suggesting	Generating suggestions for adjusting the mechanical ventilator

Randolph AG et al. User's guide to the medical literature XVIII. JAMA 1999. [Abstract]

CDS Targets are Determined by Workflow Need

Desired Outcome / Clinical Target

- Improve efficiency
- Earlier detection / screening
- Diagnosis / Treatment protocol
- Prevent adverse outcome
- Follow-up management
- Cost reductions / convenience

Target Audience

- Which member of healthcare team?
- Is intervention targeted to patients / families?

Level of Control

- Pre-emptive
- Suppressible
- Hard-stop
- Interruptive

Modes of Delivery

- Templated data-collection (if you define CDS broadly)
- Suggestion (is this the correct diagnosis?)
- Summarization & Data Visualization (eg: results review)
- Reminder
- Information / Reference Materials
- Correct errors
- Recommend change in plan

Interruptiveness

In-Line or Background

- **“Modeless”**
- “Unread lab result” indicator on toolbar
- Optional reminder for health maintenance

Popup or Interruptive

- **“Modal”**
- Alerts
- Reminders requiring acknowledgement

On demand

- Link to formulary from within order

Leapfrog Categories of CDS

- Therapeutic duplication
- Single & cumulative dose limits
- Allergies & cross allergies
- Contraindicated route of administration
- Drug-drug and drug-food interactions
- Corollary orders
- Cost of care
- Nuisance
- Contraindications / dose limits based on patient diagnosis
- Contraindications / dose limits based on patient age or weight
- Contraindications / dose limits based on laboratory studies
- Contraindications / dose limits based on radiology studies (eg: recent or ordered IV contrast)

Ten Commandments For Effective CDS

1. **Speed is everything** – expect sub-second latency
2. **Anticipate needs and deliver in real time** – e.g., showing relevant labs with med orders
3. **Fit into the user's workflow** – external tools not as good as those at POC
4. **Little things can make a big difference** – "usability matters – a lot", "make it easy to do the right thing"
5. **Physicians resist stopping** – don't tell docs to not do something without offering an alternative
6. **Changing direction is easier than stopping**
7. **Simple interventions work best** – try to fit guidelines onto a single screen
8. **Ask for additional information only when you really need it** – "likelihood of success is inversely proportional to the number of extra data elements needed"
9. **Monitor impact, get feedback, and respond**
10. **Manage and maintain your knowledge-based systems**

(Bates, JAMIA 2003)

Five Rights of CDS

- **Right Information** – quality of knowledge base
- **Right Person** – target of CDS
- **Right Format** – implementation of CDS (speed, ease of use, comprehensibility)
- **Right Channel** – mode of CDS
- **Right Time** – workflow integration

(Osheroff [illegible])

Decision Support Done Right!

Right Information

- Hey! We're out of toilet paper!

Right Person

- The person whose turn it is to buy TP

Right Format

- Modal / interruptive alert, universal visual reminder

Right Channel

- Embedded in the toilet-goer's workflow

Right Time

- **Critically, before you use the toilet**

Image Credit: Eric Shelov, MD

Evaluation of CDS

Limitations of Historical Literature

- Literature historically not-representative
  - Typically home-grown systems
  - Typically inpatient systems
- Historically, there have been methodological limitations
  - Few RCTs (this has improved in past decade)
  - Process rather than outcome measures
  - Some literature focuses on performance of diagnostic / expert systems
  - Insufficient qualitative research
  - Insufficient HCI research

Evaluation of CDS

Limitations of Current Implementations

- For most organizations, implementing and maintaining an EHR is hard enough
- Difficult to implement and evaluate CDS with constrained resources
- Generalizability is limited since implementation is so variable
- *Perhaps most importantly, we have a more nuanced appreciation of Human-Computer Interaction, Cognitive Informatics, and Usability*

Implementation Science Systematic Reviews

https://www.biomedcentral.com/collections/CCDSS

Series of reviews of CDSS effectiveness in six areas:

- Chronic disease management
- Acute care management
- Therapeutic drug monitoring and dosing
- Drug prescribing and management
- Diagnostic test ordering behavior
- Primary preventative care

Published as Open Access articles in August, 2011

Conclusion: some CDS in some settings show some process improvement, but improvements in outcomes are difficult to demonstrate or generalize

AHRQ-Funded Systematic Review

Bright *et al. Annals of Internal Medicine, 2012.*

Preventive Services: (*n* = 25; **odds ratio [OR], 1.42** [95% CI, 1.27 to 1.58])

Ordering Studies: (*n* = 20; **OR, 1.72** [CI, 1.47 to 2.00])

Prescribing Therapies: (n= 46; **OR, 1.57** [CI, 1.35 to 1.82])

*"Both commercially and locally developed CDSSs are **effective at improving health care process measures across diverse settings**, but evidence for **clinical, economic, workload, and efficiency outcomes remains sparse**. This review expands knowledge in the field by demonstrating the benefits of CDSSs outside of experienced academic centers."*

Systematic Review: Process vs. Outcome Measures

Garg et al, JAMA, 2005

Systems of interest:

- Diagnostic Systems
- Reminder Systems
- Disease Management Systems
- Drug Dosing / Prescribing

Identified 97 trials looking at practitioner performance, 64% showed benefit

Patient outcomes were not demonstrated to be impacted

- 52 trials looked at patient outcomes
- Insufficiently powered to see effect
- **Only 7 showed improvement in outcomes, none showed improvement in mortality**
- Surrogate outcomes (glycosylated Hgb, BP) were not improved

Features of Success

Kawamoto *et al., BMJ, 2005.*

Systematic review of CDS. Four predictors of improved practice:

1. Provision of CDS as part of clinical workflow
2. Provision of recommendations, not just assessments
3. Provision of CDS at time/location of decision
4. Computer based decision support

And the Dreaded “Unintended Consequences”

clipart credit: http://flaticon.com

[Campbell et al., JAMIA 2006.]

Table 2

Unintended Consequences and Their Frequencies of Occurrence

Unintended Consequence	Frequency (%) *n* = 324
More/new work for clinicians	19.8
Workflow issues	17.6
Never ending system demands	14.8
Paper persistence	10.8
Changes in communication patterns and practices	10.1
Emotions	7.7
New kinds of errors	7.1
Changes in the power structure	6.8
Overdependence on technology	5.2
Total	100

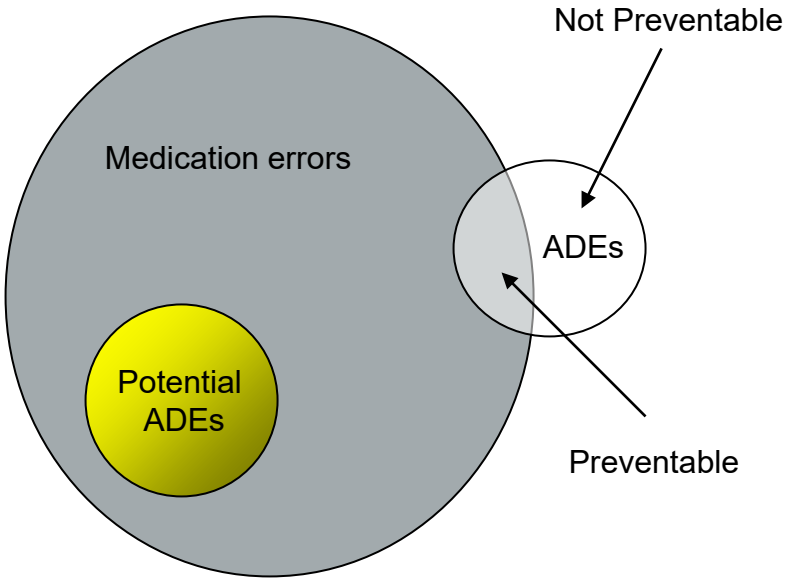
CPOE / CDS Improves Medication Safety

Clear benefit in reducing prescribing errors

- Kaushal *et al*, Arch Intern Med, 2003
- Kaushal *et al*, JAMA, 2001

Less clear that CPOE can prevent adverse drug events

- Wolfstadt *et al*, J Gen Intern Med, 2008
- van Rosse *et al*, Pediatrics, 2009
- Bright *et al*, Ann Intern Med, 2012



Modified from Kaushal et al, 2001

Knowledge Representation & Sharing

- “Curly Braces” problem
- Guideline representation & consumability
- Commercial CDS repositories
- Standards & definitions
- Opportunities for distributed CDS systems

clipart credit: http://[illegible].com

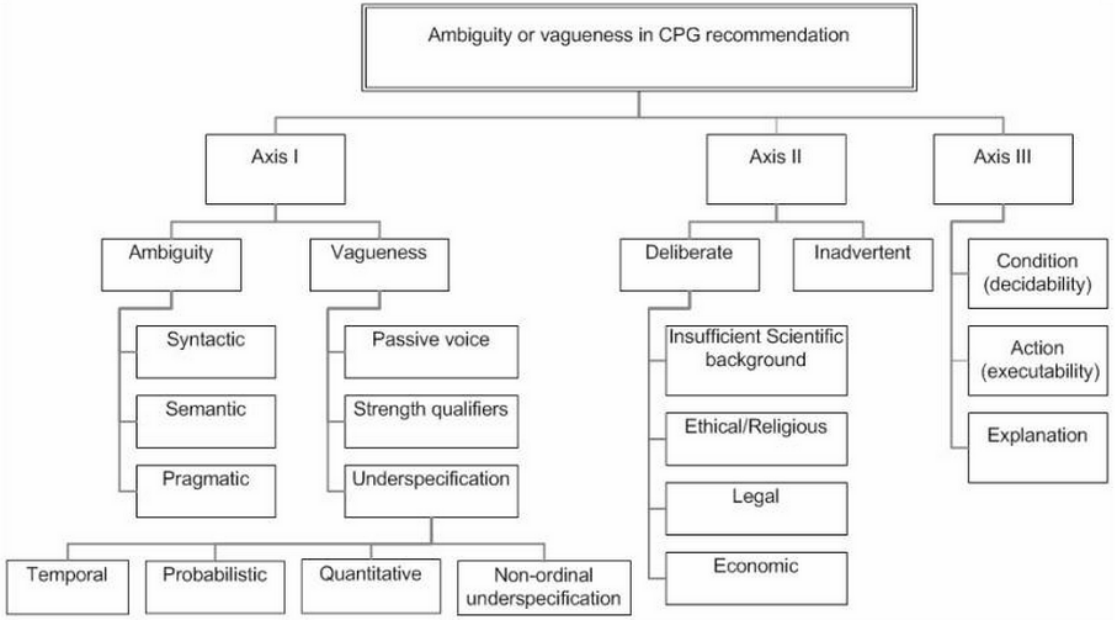
Arden Syntax

- ANSI-approved standard for encoding medical knowledge
- Knowledge bases represented as portable logic known as Medical Logic Modules or MLM
- Benefits: distributed, sharable rules
- Doesn't solve the problem of semantic interoperability: queries to local data environment differ from system to system, making MLM's not truly portable
- Local data calls are isolated in curly braces ["{}"] – hence the "curly braces problem"

```
maintenance:
  title: Alert on low hematocrit;;
library:
  purpose: Warn provider of new or worsening anemia.;;
knowledge:
  type: data-driven;;
  data:
    blood_count_storage := event {'complete blood count'};
    hematocrit := read last {'hematocrit'};
    previous_hct := read last ({'hematocrit'} where it occurred before
                    the time of hematocrit);;
  evoke: blood_count_storage;;
  logic:
    if hematocrit is not number then conclude false; endif;
    if hematocrit <= previous_hct-5 or hematocrit<30 then conclude true;
    endif;;
  action:
    write " The patient's hematocrit ("|| hematocrit ||") is low or
           falling rapidly.";;
end:
```

Image credit: De Clerq et al. Student Health Technol Inform, 2010.

Guideline Modeling



Codish S, Shiffman RN. A model of ambiguity and vagueness in clinical practice guideline recommendations. AMIA Annu Symp Proc. 2005:146-50.

Guideline Modeling

Axis 1

Syntactic – “A or B and C” (missing parentheses?)

Semantic – “I will meet you at the bank” (which bank?)

Pragmatic (conflicting recommendations)

Underspecification – “children” (include infants? Teens?)

Strength qualifiers – “recommended as probably effective”

Passive voice – “should be performed”

Axis 3

Condition – “if x-ray is not suggestive of pneumonia”

Action – “perform further evaluation”

Codish S, Shiffman RN. A model of ambiguity and vagueness in clinical practice guideline recommendations. AMIA Annu Symp Proc. 2005:146-50.

clipart credit: http:/[illegible].com

Features of Computable Guidelines

- The guidelines must first lend themselves to computation
- The representation format must allow for clinical expressivity
  - Temporal dependencies
  - Complex rules
  - Strength of evidence
  - Imperative / optional actions
- Standard vocabularies and semantics
- Interoperable
- Portable

Guideline Modeling Frameworks

- GLIF
- Protegé
- Arden Syntax – 1990, HL7 & ANSI endorsed
- GEM – ASTM standard for representation in XML
- SEBASTIEN

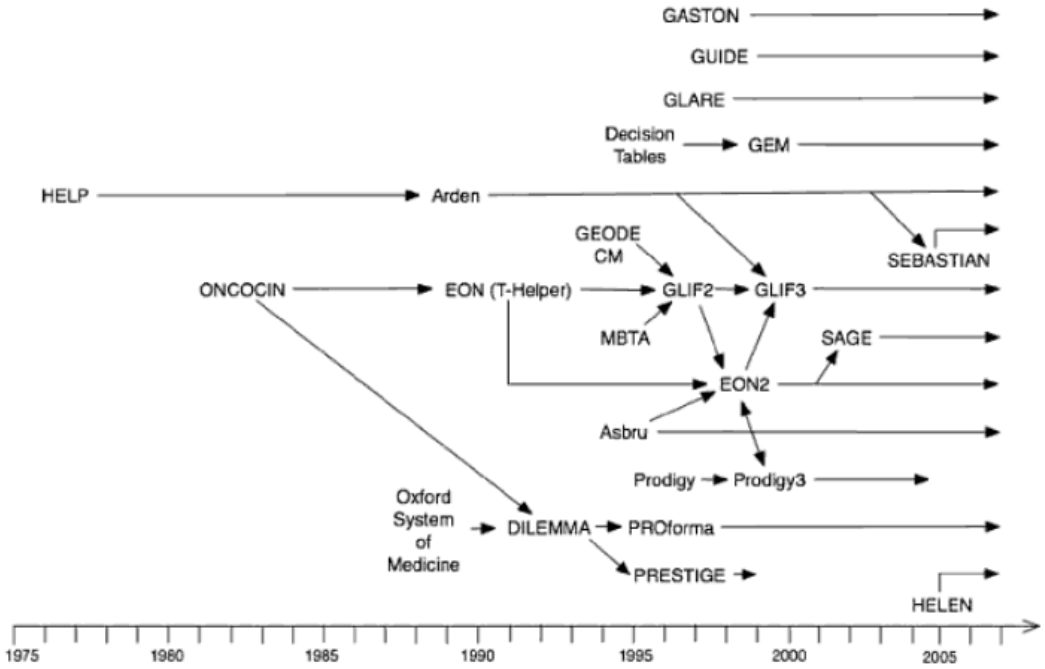


Figure 1. History of CIG approaches, positioned on a time axis (adapted from Elkin et al [10])

Knowledge Maintenance

Reliance on EHR patient data

Guideline authorship, review, update cycle

Review patterns of use – process measures, override rates, sentinel events, and other measures of CDS effectiveness

Role for service-oriented architecture for “plug-and-play” CDS systems

Office of the National Coordinator for HIT. Safety Assurance Factors for EHR Resilience (SAFER). **Self Assessment High Priority Practices**. [Link]

Clinical Knowledge Repositories

With proliferation of CDS content, there is a clear need for Clinical Knowledge Management (CKM) solutions

Recommendations

- Multi-disciplinary team to create and maintain content
- Repository with web-based access to allow anyone in to review it
- Online, collaborative tool for content development
- Enterprise-wide tool to govern use of controlled clinical terminology concepts (see Data Governance slides)

Joint Commission and CMS both require periodic review of "electronic standing orders, order sets, and protocols"

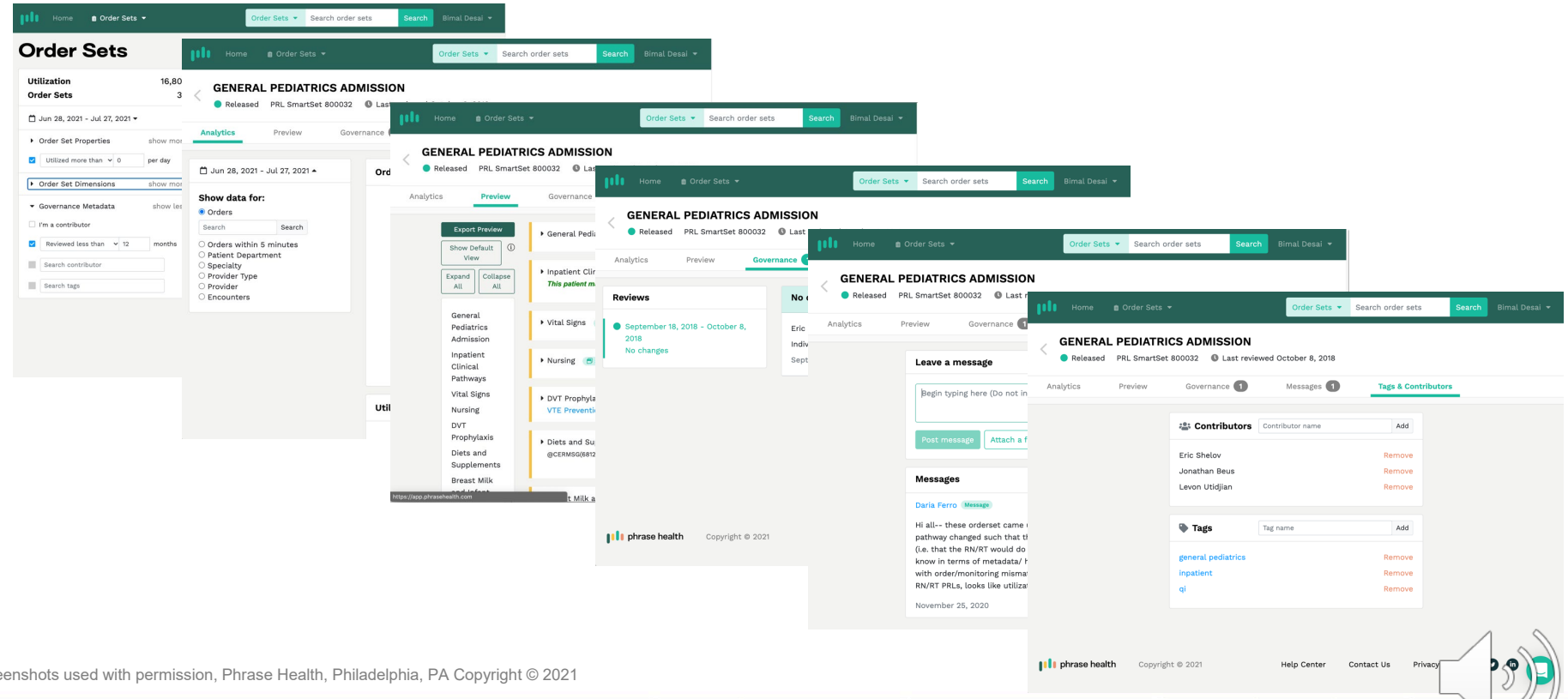
- Demonstrate review/approval by medical staff, nursing, pharmacy leadership
- Demonstrate that such orders are consistent with established guidelines
- Process for periodic review

Functions of a CKM Tool

- Represent knowledge in standard format (Arden, GEM, GLIF, etc.)
- Map knowledge to implementation in CIS
- Identify content owner for each piece of clinical content (alert, orderset, patient education)
- Send reminders for editorial lifecycle
- Cascading notifications when content changes (e.g. formulary → pharmacy → orderable item → orderset)
- Ideally, a way to "learn" new content based on patterns of use (e.g. suggest new ordersets based on common use)

Source: Sittig *et al. Int J Med* . Jan 2010.

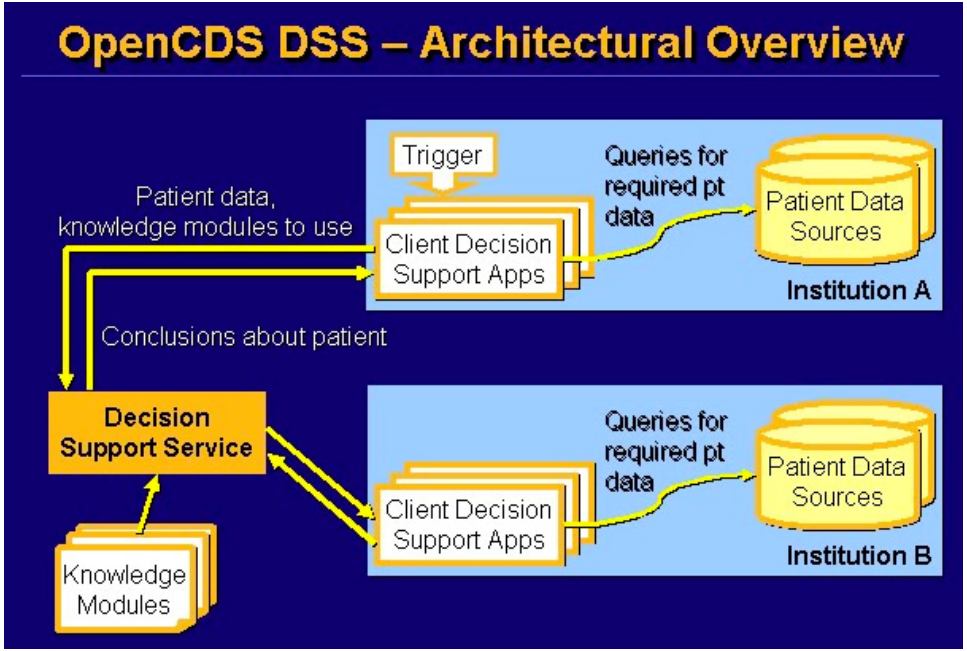
Example CKM Tool in Use



Screenshots used with permission, Phrase Health, Philadelphia, PA Copyright © 2021

OpenCDS (www.opencds.org)

- Uses the May 2011 HL7 standard specification for a Decision Support Service
- Built using open source software tools
- Robust authoring environment for rules
- Integration with standard terminologies (ICD10, SNOMED, LOINC, RxNORM)
- Can be integrated with other types of CDS tools, such as the HL7 Infobuttons standard



SMART on FHIR: The End of Curly Braces?

Covered in more detail in Standards lecture and in supplemental materials

HL7 v2 = pipe-delimited, encoding depends on position in string

HL7 v3 = Encoded against the Reference Implementation Model (RIM) in XML, document-centric

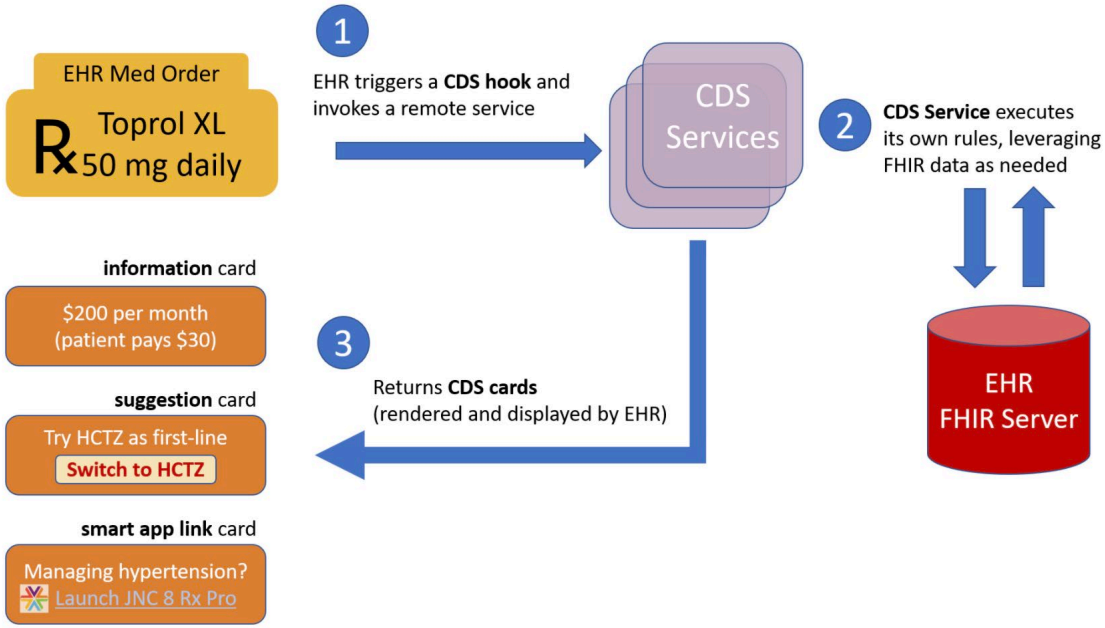
HL7 FHIR = RESTful syntax, designed for ease of use by developers

HL7 V2	HL7 CDA	HL7 FHIR
PID||0493575^^^2^ID 1|454721||**DOE^JOHN ^^^^**|DOE^JOHN^^^^| 19480203|M||B|254	<admission document> <patient> **<name first = "John" last = "Doe"/>** <age 23/> </patient> </admission document>	String name; name = **FHIR.patient()**

Table credit: http://sil-asia.org/exploring-hl7-standards/

CDS Hooks

- Technology developed by SMART project
- Specifies how EHR triggers can invoke external CDS services automatically
- Not yet a standard, but addresses a major barrier to computable, shareable decision support



Source: https://cds-hooks.org/

Alert Fatigue

Refers to state of user resistance to guidance provided by alerts, even those that might offer possible benefit or reduce harm, presumably because they are overwhelmed by unimportant alerts

Difficult to measure

- Literature typically uses alert override rates as proxy for “low utility”
- EHR systems offer different alert designs for Drug-Drug interactions, custom CDS, and other alert types. Studies may be comparing apples to oranges.

Difficult to define

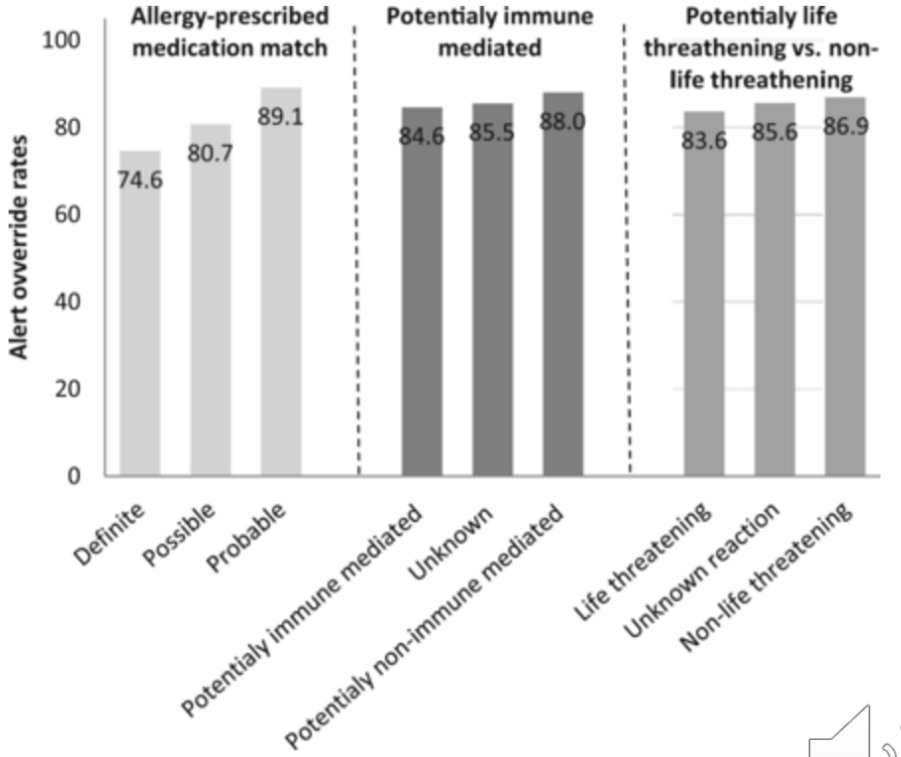
- What is an “appropriate” override rate?

Counterintuitive results

- Reducing alert burden dramatically does not dramatically reduce override rate
- In fact, EHR override rates have remained flat or perhaps increased in the past decade

Alert Fatigue

- Overall override rates increased between 2004 and 2013 from 83.3% to 87.6%
- Exact, definite allergen matches least likely to be overridden



Topaz *et al*, JAMIA 2016

Alert Fatigue

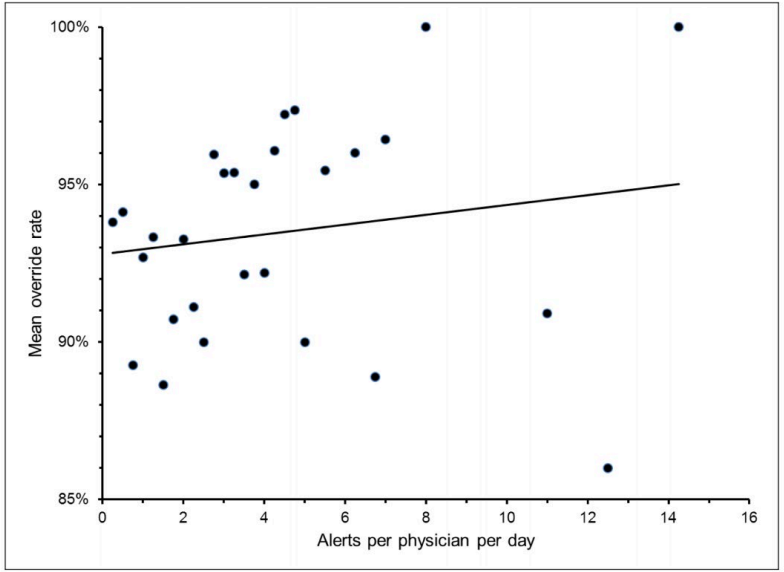


Fig. 3 Physician override rate does not correlate with viewed alert quantity. Markers denote mean override rates among each set of physicians with the same alert quantity. R2 = 0.03, p = 0.41.

Research Article

aci Applied Clinical Informatics 802

Drug interaction alert override rates in the Meaningful Use era

No evidence of progress

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Bryant *et al, Applied Clinical Informatics, 2016*

Recommendations to Address Alert Fatigue

1. Classify alerts in to 3 levels – minor, moderate, severe
2. Develop a core set of critical drug drug interactions
3. Classify alerts into active and passive, only make critical alerts active (interruptive)
4. Conduct training on new improvements
5. Develop systems with automated feedback/learning to identify and move alerts from active/interruptive to passive/non-interruptive

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Supplement: SMART on FHIR® History

2009: NEJM article "No small change for the health information economy" by Mandl & Kohane suggested that EHRs should be an extensible platform, like an iPhone™

- Liquidity of data – reduce impediment to data transfer
- Substitutability of applications – modular and interoperable
- Built to open standards for open- and closed-source developers
- Development of an ecosystem of apps, free marketplace of ideas

Supplement: SMART on FHIR® History

2010: SMART = Substitutable Medical Applications and Reusable Technologies

- 1st Gen: HTML, JavaScript, OAuth, Resource Description Framework (RDF) for metadata, and common terminologies like LOINC, RxNorm.
- Lacked a standard for sharing granular clinical data
- Poor initial uptake of "SMART Classic" by EHR vendors

2011: HL7 community concerned that HL7 V3 was not gaining traction

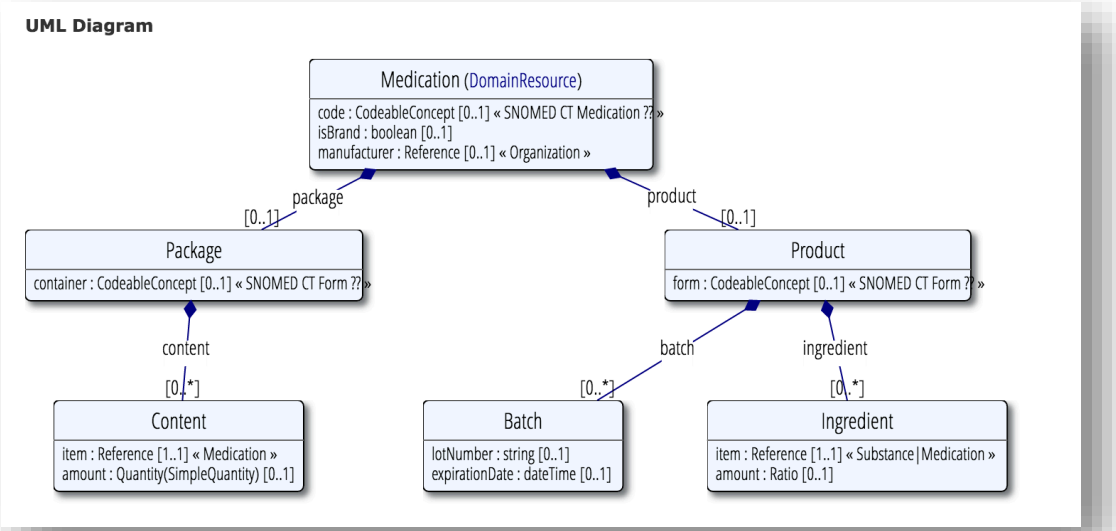
- Led to emergence of Resources for Health --> Fast Healthcare Interoperability Resources (FHIR®)

2013: SMART team adopts FHIR® standard

Supplement: SMART on FHIR® Technical Overview

FHIR® represents clinical data as “resources”

http://www.hl7.org/implement/standards/fhir/resourcelist.html



UML diagram for FHIR® “Medication” Resource

Supplement: SMART on FHIR® Technical Overview

FHIR® resources can be represented as XML or JSON ("javascript object notation"), both very convenient ways for developers to access and manipulate data.

JSON is one way to "serialize" a software object (instance of a class in object-oriented programming) to allow representation as a flat file, string, or message

FHIR allows developers to build "**RESTful**" applications

- **REST** = Representational State Transfer
- Acts on a **Universal Resource Identifier** (URI)
- Uses HTTP methods (PUT, GET, POST, DELETE; which loosely represent the "create, read, update, delete" functions of a database)

JSON Template

```
{
  "resourceType" : "Medication",
  // from Resource: id, meta, implicitRules, and language
  // from DomainResource: text, contained, extension, and modifierExtension
  "code" : { CodeableConcept }, // Codes that identify this medication
  "isBrand" : <boolean>, // True if a brand
  "manufacturer" : { Reference(Organization) }, // Manufacturer of the item
  "product" : { // Administrable medication details
    "form" : { CodeableConcept }, // powder | tablets | carton +
    "ingredient" : [{ // Active or inactive ingredient
      "item" : { Reference(Substance|Medication) }, // R!  The product contained
      "amount" : { Ratio } // Quantity of ingredient present
    }],
    "batch" : [{ //
      "lotNumber" : "<string>", //
      "expirationDate" : "<dateTime>" //
    }]
  },
  "package" : { // Details about packaged medications
    "container" : { CodeableConcept }, // E.g. box, vial, blister-pack
    "content" : [{ // What is  in the package
      "item" : { Reference(Medication) }, // R!  A product in the package
      "amount" : { Quantity(SimpleQuantity) } // Quantity present in the package
    }]
  }
}
```

JSON specification for FHIR® "Medication" Resource

Supplement: SMART on FHIR® Technical Overview

JSON representation of injectable Paclitaxel (compare to JSON template on previous slide)


```
{
  "resourceType": "Medication",
  "id": "medexample016",
  "text": {
    "status": "generated",
    "div": "<div><p><b>Generated Narrative with Details</b></p><p><b>id</b>: medexample016</p><p
><b>code</b>: Paclitaxel 6mg/mL injection solution 5mL vial (product) <span>(Details : {SNOMED C
T code '400352007' = '400352007', given as 'Paclitaxel 6mg/mL injection solution 5mL vial (produ
ct)'})</span></p><p><b>isBrand</b>: false</p><h3>Products</h3><table><tr><td>-</td><td><b>Form</
b></td></tr><tr><td>*</td><td>Parenteral dosage form product <span>(Details : {SNOMED CT code '4
40132002' = '440132002', given as 'Parenteral dosage form product'})</span></td></tr></table></d
iv>"
  },
  "code": {
    "coding": [
      {
        "system": "http://snomed.info/sct",
        "code": "400352007",
        "display": "Paclitaxel 6mg/mL injection solution 5mL vial (product)"
      }
    ]
  },
  "isBrand": false,
  "product": {
    "form": {
      "coding": [
        {
          "system": "http://snomed.info/sct",
          "code": "440132002",
          "display": "Parenteral dosage form product"
        }
      ]
    }
  }
}
```

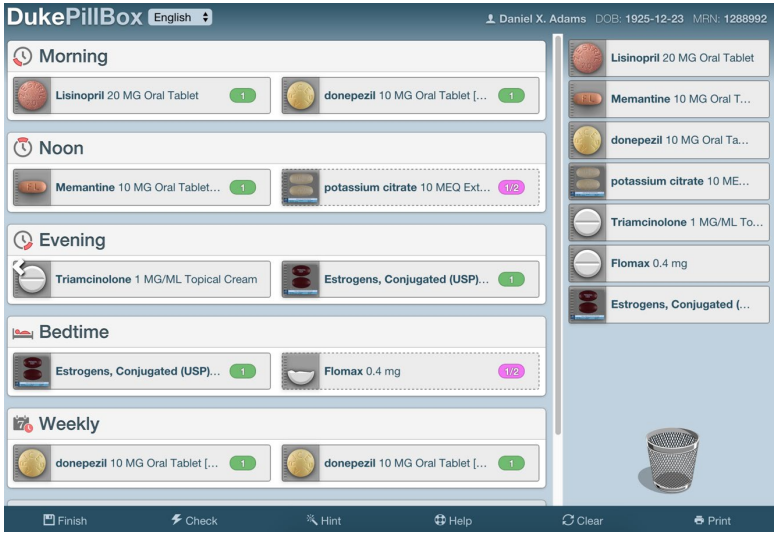

“code” attribute refers to SNOMED concept “400352007” which unambiguously refers to “paclitaxel 6mg/ml injection solution, 5ml vial”

“form” attribute refers to SNOMED concept “440132002” which unambiguously refers to “parenteral dosage form product”

FHIR® Profiles are used to constrain or extend **FHIR® Resources**

Developers can use FHIR® Profiles to validate that payload meets application needs.

Supplement: SMART on FHIR® Technical Overview



Example SMART app “Duke PillBox” [Link]

FHIR® specifies

- data model (resources)
- format (XML, JSON)
- method of access (RESTful API)

SMART additionally provides

- authorization (OAuth2),
- authentication (OpenID Connect)
- mechanism for EHR UI integration