HL7-Standards zur medizinischen Wissensverarbeitung: Arden-Syntax und ArdenML

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- Anwendungen (Adlassnig)
- Klinische Perspektiven (Binder)
- Verantwortung und Medizinprodukt (Adlassnig)

HL7 – global interoperability standards

- HL7 provides standards for interoperability
  - improve care delivery, optimize workflow, reduce ambiguity and enhance knowledge transfer
- HL7 Standards
  - Version 2.x messaging standard
  - Version 3: specifications based on HL7's Reference Information Model (RIM) – for messaging and documents
  - CDA® (Clinical Document Architecture): a V3 based document markup standard that specifies the structure and semantics of "clinical documents" → CDA implementation guides
  - Vocabulary Standards
  - CTS2 (Common Terminology Services) – services for accessing and managing terminological content
  - ARDEN Syntax
  - …
- HL7 Base Standards are licensed – but that license is free ("license at no cost")

About HL7

- **Health Level Seven International** (HL7), founded in 1987
  - a not-for-profit, ANSI-accredited standards developing organization in healthcare-IT
  - collaborates with other SDO like ISO, DICOM, IHTSDO, IHE, …
  - headquarter: USA (Ann Arbor, MI)
  - >2.300 members (healthcare providers, government agencies, vendor community, …)
  - 34 affiliate organizations around the world (18 in Europe)

- **HL7 Austria**
  - Founded in 2007
  - Activities: information source, support, ballots (eg. CDA IG), e-Learning, courses, meetings/conferences, "Austrian interoperability forum"
  - www.hl7.at Twitter https://twitter.com/HL7_Austria

ELGA & Decision Support

- ELGA has (momentary) no decision support mechanisms, but…

- ELGA gives access to a collection of relevant and highly structured and semantic interoperable healthcare documents (HL7 CDA Rel. 2)
- ELGA provides supplemental standardized information for a patient
  → Local EHR can be completed with downloaded information from ELGA

- The aggregated data pool (local EHR+ELGA) may be used for clinical decision support!
  - Example: ELGA medications, discharge diagnoses, lab results, …

HL7 activities toward clinical decision support standards

- Arden Syntax for Medical Logic Systems, Version 2.10 (May, 2014)
- HL7 Version 3 Standard: Gello; A Common Expression Language, Release 2 (April 2010)
- HL7 Version 3 Standard: Virtual Medical Record for Clinical Decision Support (vMR-CDS) Logical Model, Release 2 (January 2014)
- HL7 Version 3 Standard: Clinical Decision Support Knowledge Artifact Specification, Release 1.1 (April 2014)
- **…**

http://www.hl7.org/implement/standards/index.cfm?ref=nav

Arden Syntax and Health Level Seven (HL7)

- A standard language for writing situation-action rules that can trigger alerts based on abnormal clinical events detected by a clinical information system.
- Each module, referred to as a medical logic module (MLM), contains sufficient knowledge to make a single decision.
  - ➢ extended by packages of MLMs for complex clinical decision support
- The Health Level Seven Arden Syntax for Medical Logic Systems, Version 2.9—including fuzzy methodologies—was approved by the American National Standards Institute (ANSI) and by Health Level Seven International (HL7) on 14 March 2013
- Version 2.10---including ArdenML, an XML-based representation of Arden Syntax MLMs---was approved on 6 May 2014
  - ➢ continuous development since 1989

General MLM Layout

- Maintenance Category
- Library Category
- Knowledge Category
- Resources Category

Identify an MLM

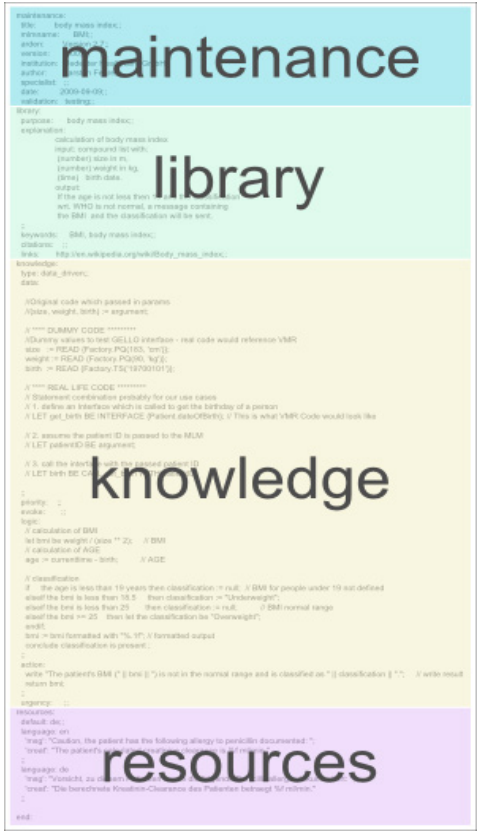
Data Types

Operators

- Basic Operators
- Curly Braces
- List Operators
- Logical Operators
- Comparison Operators
- String Operators
- Arithmetic Operators
- Other Operators

Control Statements

Call/Write Statements and Trigger



Sample MLM (excerpt)

```
logic:
  result := new bmiResult; // create an empty result object

  weight := latest of weights; // get the latest weight from the list

  size := call mlmForReadSize with patientID; // get the size of the patient calculated by another MLM

  result.bmi := weight / (size ** 2); // calculation of BMI
  age := currenttime - birth; // calculation of AGE

  // classification - the classification is only valid for patients older than 19
  if the age is less than 19 years then result.classification := null;
  elseif the result.bmi is less than 18.5 then result.classification := localized 'under';
  elseif the result.bmi is less than 25 then result.classification := null;
  else let the result.classification be localized 'over';
  endif;

  result.bmi := result.bmi formatted with localized 'msg'; // construct the localized message

  if (time of weight) is before (currenttime - 6 months) then
    conclude false; //no bmi calculation if the latest measure was 6 months ago
  else
    conclude result.classification is present ; // if there is a classification, execute the action slot
  endif;

;;
```

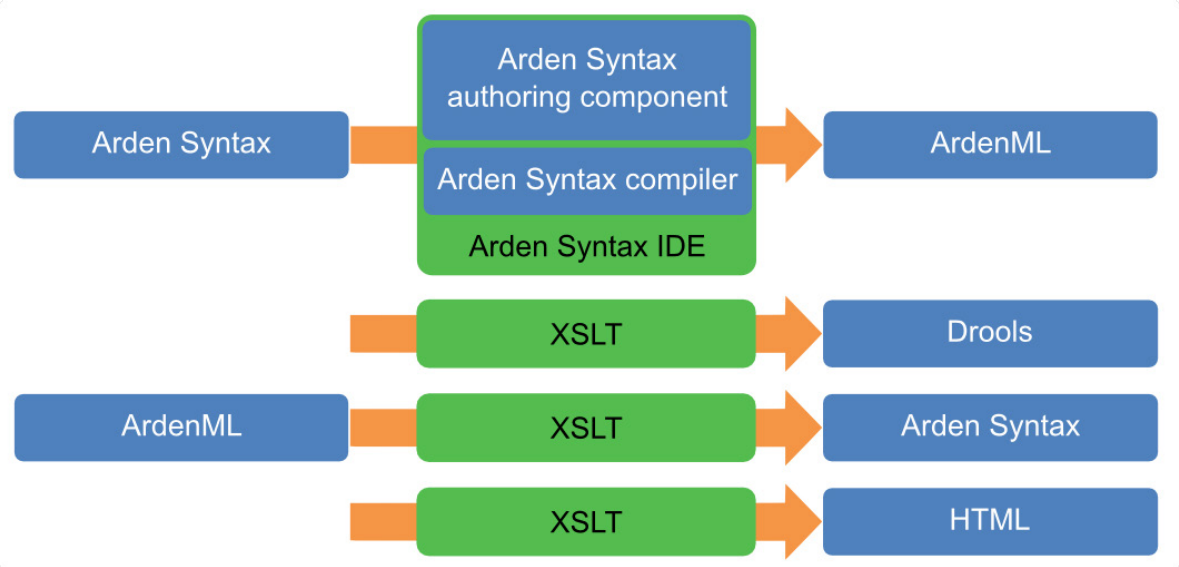
ArdenML: Objectives and applications

- Provide a complete XML schema for Version 2.10 of the Arden Syntax to express MLMs in XML
- Thus, Arden Syntax is now compatible with all other HL7 standards based on XML (HL7 version 3, VmR, and others)
- Further benefit: To be able to use available XML tools

ArdenML: Example

```
<Library>
    <Purpose>Test</Purpose>
    <Explanation></Explanation>
    <Keywords></Keywords>
</Library>
<Knowledge>
    <Type>data_driven</Type>
    <Data></Data>
    <Evoke></Evoke>
    <Logic>
        <Assignment>
            <Identifier var='var1' />
            <Assigned>
                <Value otype='time'>1990-03-15T15:00:00</Value>
            </Assigned>
        </Assignment>
        <Assignment>
            <Identifier var='res1' />
            <Assigned>
                <ReplaceYearWith>
                    <Identifier var='var1' />
                    <Value otype='number'>2011</Value>
                </ReplaceYearWith>
            </Assigned>
        </Assignment>
        <Assignment>
            <Identifier var='res2' />
            <Assigned>
                <ReplaceYearWith>
                    <Identifier var='var1' />
                    <List>
                        <Value otype='number'>2011</Value>
                        <Value otype='number'>2010</Value>
                    </List>
                </ReplaceYearWith>
            </Assigned>
```

Cross compilation/transformation of Arden Syntax to/from ArdenML



Team effort by Intermountain Hospital, Salt Lake City, Utah, U.S.A., and Medexter Healthcare, Vienna, Austria

Computers in clinical medicine—steps of natural progression

- step 1: patient administration
  - admission, transfer, discharge, and billing

- step 2: documentation of patients' medical data
  - electronic health record: all media, distributed, life-long (partially fulfilled)

- step 3: patient and hospital analytics
  - data warehouses, quality measures, reporting and research databases, patient recruitment

    … population-specific

- step 4: clinical decision support
  - safety net, quality assurance, evidence-based

    … patient-specific

History

- Clay tablets with cuneiform writing from New Babylonian (about 650 B.C.)
  - instructions to medical examination, diagnosis, and prognosis

- "Reasoning Foundations of Medical Diagnosis" by Ledley and Lusted in Science (1959)
  - computer-assisted medical diagnosis and therapy

- medical expert system MYCIN by Shortliffe et al. (Stanford University, 1975)
  - diagnostic and therapeutic proposals for patients suffering from infectious diseases (evaluation JAMA, 1979)

Antimicrobial Selection by a Computer

A Blinded Evaluation by Infectious Diseases Experts

Victor L. Yu, MD; Lawrence M. Fagan; Sharon M. Wraith; William J. Clancey; A. Carlisle Scott, MS; John Hannigan, MS; Robert L. Blum, MD; Bruce G. Buchanan, PhD; Stanley N. Cohen, MD

• **An evaluation of a computer-based consultation system called MYCIN was made. Eight independent evaluators with special expertise in the management of meningitis compared MYCIN's choice of antimicrobials with the choices of nine human prescribers for ten test cases of meningitis. MYCIN received an acceptability rating of 65% by the evaluators; the corresponding ratings for acceptability of the regimen prescribed by the five faculty specialists ranged from 42.5% to 62.5%. The system never failed to cover a treatable pathogen while demonstrating efficiency in minimizing the number of antimicrobials prescribed. The study design may be useful in assessing the performance of other computer-based clinical decision-making systems.**

(*JAMA* 242:1279-1282, 1979)

DURING the last two decades, many computer programs have been developed to assist physicians in the diagnosis or treatment of a variety of medical disorders.[1] However, to our knowledge, the medical accuracy of these programs has not undergone clinical evaluation by independent experts. We present a comparison of meningitis before the causative agent had been identified.

The computer program, MYCIN, provides advice for the diagnosis of diseases and the treatment of patients with infectious diseases.[2,3] During the last five years, MYCIN's extensive knowledge base and its therapy-selection process have been

therapy, MYCIN takes into account the specific clinical situations (eg, trauma, neurosurgery), host factors (eg, age, immunosuppression), and the possible presence of unusual pathogens (eg, *Francisella tularensis*, *Candida* non-*albicans*). In selecting antimicrobial therapy, the system considers antimicrobial factors (eg, organism susceptibility, synergistic combinations) and relative contraindications (eg, patient allergies, poor response to prior therapy).

When knowlege about a new area of infectious disease is incorporated into MYCIN's knowledge base, the system's performance is evaluated to determine whether its therapeutic regimens are as reliable as the regimens that an infectious diseases specialist would recommend. An evaluation of the system's ability to diagnose and treat patients with bactere-

Artificial Intelligence (AI)—applicable to clinical medicine

- *Definition*: AI is the science of artificial simulation of human thought processes with computers.

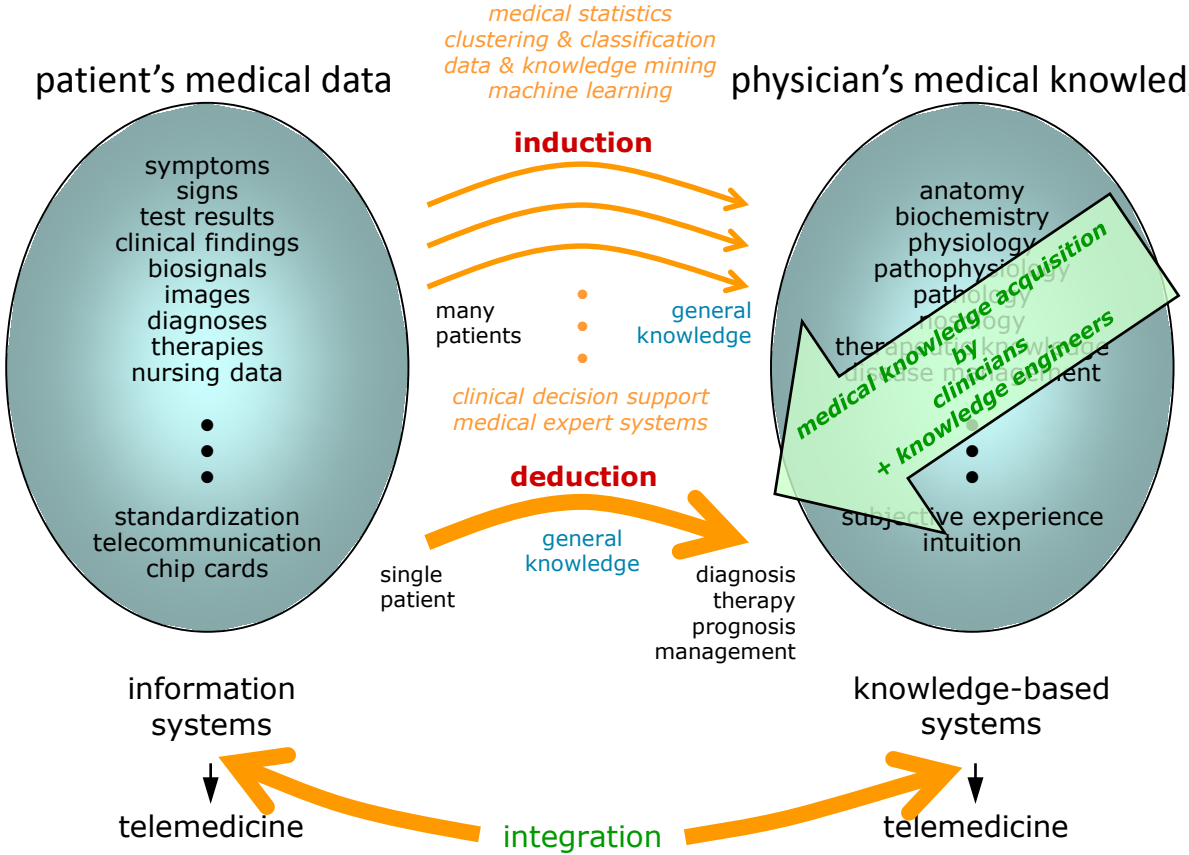
  from: Feigenbaum, E.A. & Feldman, J. (eds.) (1995) *Computers & Thought*. AAAI Press, Menlo Park, back cover.

- It is the decomposition of an entire clinical thought process and its separate artificial simulation—also of simple instances of "clinical thought"—that make the task of AI in clinical medicine manageable.

- A functionally-driven science of AI that extends clinicians through computer systems step by step can immediately be established.

artificial-intelligence-augmented clinical medicine

Medical information and knowledge-based systems

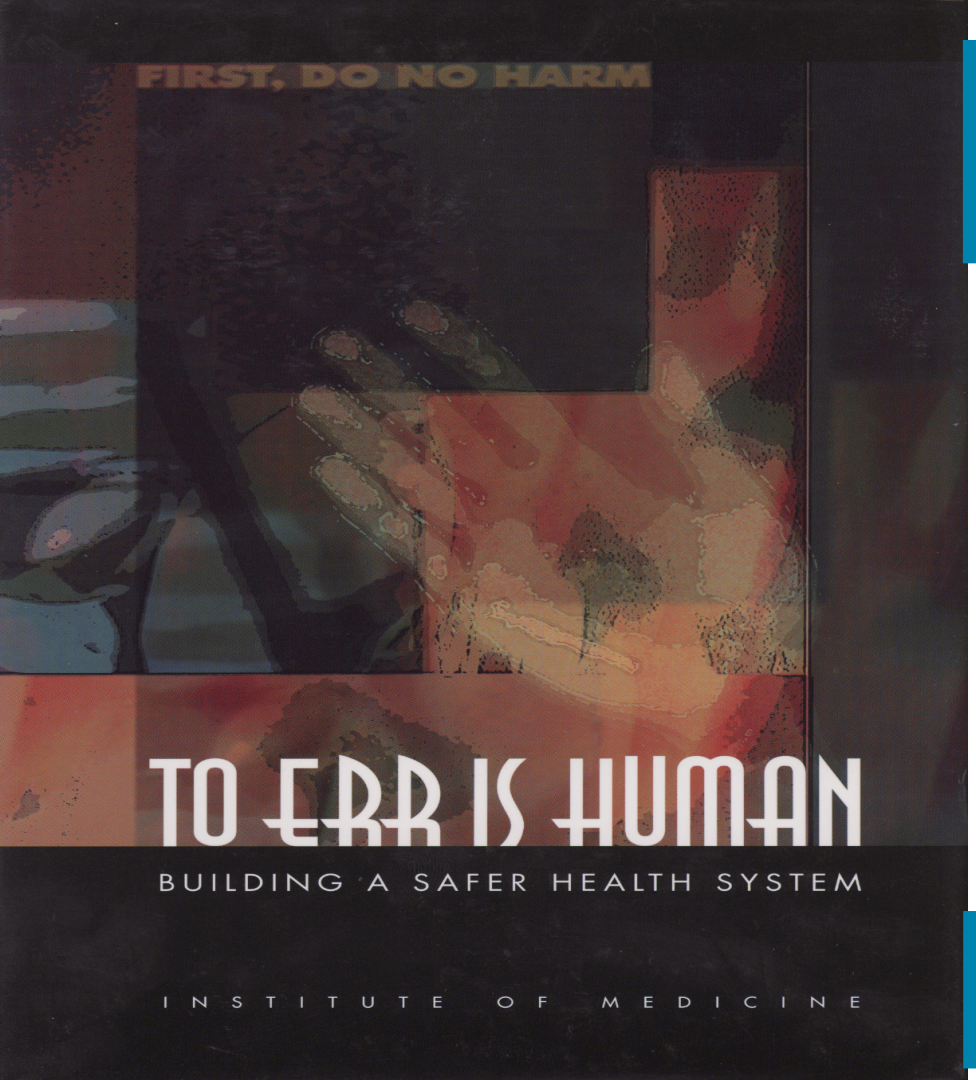


Clinical decision support and quality assurance

patients' structured medical data

diagnostic support • clinical alerts, reminders, calculations • data interpretation, (tele)monitoring • differential diagnostic consultation – rare diseases, rare syndromes – further or redundant investigations – pathological signs accounted for • consensus-criteria-based evaluation – definitions, classification criteria	**therapy advice** • drug alerts, reminders, calculations – indication, contraindications, redundant medications, substitutions – adverse drug events, interactions, dosage calculations, consequent orders • management of antimicrobial therapies, resistance • (open-loop) control systems
prognostic prediction • illness severity scores, prediction rules • trend detection and visualization	**patient management guidelines & quality assurance** • evidence-based reminders and processes • computerized clinical guidelines, protocols, SOPs • healthcare-associated infection surveillance

highly-structured medical knowledge



- studies in Colorado and Utah and in New York (1997)
  - errors in the delivery of health care leading to the death of as many as 98,000 US citizens annually

- causes of errors
  - error or delay in diagnosis
  - failu… …y indicated tests
  - use… …d tests or therapy
  - failure to act on results of testing or monitoring
  - error in the performance of a test, procedure, or operation
  - error in administering the treatment
  - error in the dose or method of using a drug
  - avoidable delay in treatment or in responding t… …st
  - i… … indicated) care
  - failure … communication
  - eq…pment failure

errors

prevention

- prevention of errors
  - we must systematically design safety into processes of care

Perspectives JAMIA on Informatics

AMIA Board White Paper ■

Core Content for the Subspecialty of Clinical Informatics

Reed M. Gardner, PhD, J. Marc Overhage, MD, PhD, Elaine B. Steen, MA,, Benson S. Munger, PhD, John H. Holmes, PhD, Jeffrey J. Williamson, Don E. Detmer, MD, MA, for the AMIA Board of Directors

Abstract The Core Content for Clinical Informatics defines the boundaries of the discipline and informs the Program Requirements for Fellowship Education in Clinical Informatics. The Core Content includes four major categories: fundamentals, clinical decision making and care process improvement, health information systems, and leadership and management of change. The AMIA Board of Directors approved the Core Content for Clinical Informatics in November 2008.

■ **J Am Med Inform Assoc.** 2009;16:153–157. DOI 10.1197/jamia.M3045.

Background

The Core Content for a medical subspecialty defines the boundaries of the discipline and informs the Program Requirements for Fellowship Education. Program Requirements identify the knowledge and skills that must be mastered through the course of fellowship training and specify accreditation requirements for training programs.[1] The American Board of Medical Specialties considers these two documents along with other requirements and factors when deciding whether to establish a new medical subspecialty. The Core Content for Clinical Informatics is the result of a two-year national development process initiated by the American Medical Informatics Association and supported by the Robert Wood Johnson Foundation.[2] In November 2008, the AMIA Board of Directors approved both the Core Content and Program Requirements for clinical informatics.

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The American Medical Informatics Association (AMIA) Board of Directors thanks the members of the Clinical Informatics Core Content team for their thoughtful and energetic discussions that resulted in this document. Team members included: Joan S. Ash, PhD, MBA; James J. Cimino, MD; H. Dominic Covvey, MSc; Reed M. Gardner (Chair), PhD; John H. Holmes, PhD; Nancy C. Nelson, MS; J. Marc Overhage, MD, PhD (Vice Chair); Charles Safran, MS, MD; Richard N. Shiffman, MD, MCIS; and Heiko Spallek, DMD, PhD. AMIA acknowledges the contributions of over fifty reviewers whose input strengthened the core content. AMIA thanks the Robert Wood Johnson Foundation for generously supporting this project.

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Definition and Description of the Subspecialty

Clinical informaticians transform health care by analyzing, designing, implementing, and evaluating information and communication systems that enhance individual and population health outcomes, improve patient care, and strengthen the clinician-patient relationship.

Clinical informaticians use their knowledge of patient care combined with their understanding of informatics concepts, methods, and tools to:

- assess information and knowledge needs of health care professionals and patients,
- characterize, evaluate, and refine clinical processes,
- develop, implement, and refine clinical decision support systems, and
- lead or participate in the procurement, customization, development, implementation, management, evaluation, and continuous improvement of clinical information systems.

Physicians who are board-certified in clinical informatics collaborate with other health care and information technology professionals to promote patient care that is safe, efficient, effective, timely, patient-centered, and equitable.

As illustrated in Figure 1, clinical informatics encompasses three spheres of activity:

- clinical care (i.e., the provision of clinical services to an individual patient),
- the health system (i.e., the structures, processes, and incentives that shape the clinical care environment; this includes major health domains such as public health, population health, personal health, health professional education, and clinical research, in addition to clinical care),

A "holy grail" of clinical informatics is scalable, interoperable clinical decision support.

according to

Kensaku Kawamoto

HL7 Work Group Meeting,

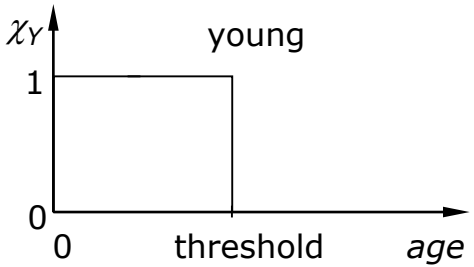
San Diego, CA, September 2011

Fuzzy Arden Syntax: Modelling uncertainty in medicine

- linguistic uncertainty
  - due to the unsharpness (fuzziness) of boundaries of linguistic concepts; gradual transition from one concept to another
  - modeled by fuzzy sets, e.g., fever, increased glucose level

- propositional uncertainty
  - due to the uncertainty (or incompleteness) of medical conclusions; includes definitional and causal, statistical and subjective relationships
  - modeled by truth values between zero and one, e.g., usually, almost confirming

Crisp sets vs. fuzzy sets



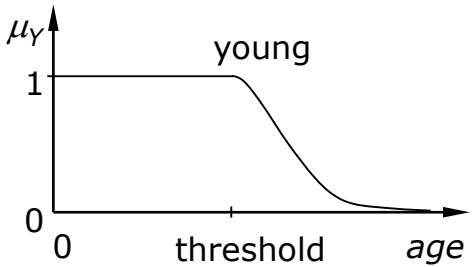
yes/no decision

$U = [0, 120]$

$Y \subseteq U$ with $Y = \{(\chi_Y(x)/\ x) \mid x \in U\}$

$\chi_Y: U \rightarrow \{0, 1\}$

$$\chi_Y(x) = \begin{cases} 0 & x > \text{threshold} \\ 1 & x \leq \text{threshold} \end{cases} \qquad \forall\ x \in U$$



gradual transition

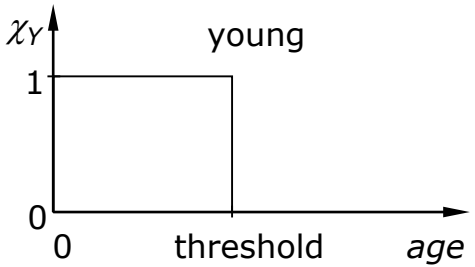
$U = [0, 120]$

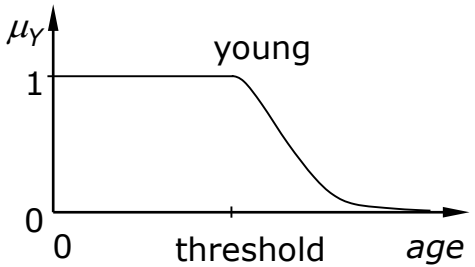
$Y \subseteq U$ with $Y = \{(\mu_Y(x)/\ x) \mid x \in U\}$

$\mu_Y: U \rightarrow [0, 1]$

$$\mu_Y(x) = \begin{cases} \dfrac{1}{1 + (0.04\ x)^2} & x > \text{threshold} \\ 1 & x \leq \text{threshold} \end{cases} \qquad \forall\ x \in U$$

Crisp sets vs. fuzzy sets





"arbitrary" yes/no decisions

- cause of unfruitful discussions
- often simply wrong

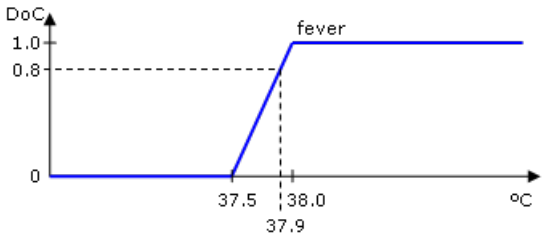
"intuitive" gradual transitions

Clinical concepts and relationships between them

truth value

$$\left(S_1 \wedge S_2\right) \vee \neg S_3 \xrightarrow{t} D$$

DoC



Arden Syntax

What is Arden Syntax ?

- … a language used for representing and sharing medical knowledge.
- … used for sharing of computerized health knowledge bases across personnel, information systems, and institutions.
- … organized using modules, while each module, referred to as a Medical Logic Module (MLM), contains sufficient knowledge to make a single decision.
- … an executable format which can be used by clinical decision support systems.

Arden Syntax – Fundamentals I

- In Arden Syntax, medical knowledge is arranged within Medical Logic Modules (MLMs)
- Each MLM represents sufficient knowledge to make a single clinical decision
- One or more MLMs are stored within a file that has the extension ".mlm"
- Each MLM is well organized and structured into categories and slots with specific content
- An MLM is composed of slots, grouped into the following **four** required **categories: maintenance**, **library**, **knowledge**, and **resources**
- Categories must appear in the correct order
- Within each category is a set of **slots** that must appear in the correct order, too

```
maintenance:
  title:          [TITLE_(needed)];;
  mlmname:        [MLM-NAME_(needed)];;
  arden:          Version 2.5;;
  version:        [MLM-VERSION_(needed)];;
  institution:    [INSTITUTION_(needed)];;
  author:         ;;
  specialist:     ;;
  date:           [DATE];;
  validation:     testing;;
library:
  purpose:        ;;
  explanation:    ;;
  keywords:       ;;
  citations:      ;;
  links:          ;;
knowledge:
  type:           data_driven;;
  data:           ;;
  priority:       ;;
  evoke:          ;;
  logic:
    conclude true;
  ;;
  action:
  ;;
  urgency:        ;;
end:
```

Arden Syntax – Fundamentals II

- MLMs are working in close contact with their host system. Ways of interaction are:
  - **Input**: By calling an MLM, an input parameter can be committed
  - **Curly Brace Expressions**: So called "curly brace expressions" implement a special kind of dynamic interaction between MLMs and host systems
  - **Write Statements**: Texts can be written to destinations that are maintained by the host system
  - **Output**: Analogous to the input parameter, data can be committed from the MLM to the host system after the execution of the MLM has finished
- In order to start the execution of an MLM, an engine is needed that handles communication with the host system and can tell which of the MLMs are available
- Ways to start running an MLM:
  - **MLM call**: An MLM is directly called
  - **Event call**: Any MLM that listens to a specific event is executed

Sample MLM

- Some of the operators and concepts can be seen in the following sample MLM that calculates the body mass index (BMI) of a patient:

```
maintenance:
  title: simple body mass index;;
  mlmname: BMI_HowTo;;
  arden: Version 2.7;;
  version: 1.00;;
  institution: Medexter Healthcare GmbH;;
  author: Karsten Fehre;;
  specialist: ;;
  date: 2010-09-09;;
  validation: testing;;
library:
  purpose: body mass index;;
  explanation: calculation of body mass index;;
  keywords: BMI, body mass index;;
  citations: ;;
  links: http://en.wikipedia.org/wiki/Body_mass_index;;
```

Sample MLM (cont.)

```
knowledge:
  type: data_driven;;
  data:

    // MLM that contains the interface definition "LET get_birth BE INTERFACE {Patient.dateOfBirth}; "
    mlmImport       := MLM 'interface_birthday_definition';

    // include
    include mlmImport;

    mlmForReadSize  := MLM 'read_Size_MLM'; // MLM which can read the current size of the patient from the DB

    LET patientID BE argument; // the patient ID is passed to the MLM

    LET birth     BE CALL get_birth WITH patientID; // call the interface with the passed patient ID

    // read all measured weights from the database
    LET weights   BE READ {SELECT measured_weight FROM DB WHERE patID = patientID };

    LET userEvent BE EVENT {getBMI};

    // object declaration
    bmiResult := object [bmi, classification];

  ;;
  priority: ;;
  evoke:
    userEvent;
  ;;
```

Sample MLM (cont.)

```
logic:
  result := new bmiResult; // create an empty result object

  weight := latest of weights; // get the latest weight from the list

  size := call mlmForReadSize with patientID; // get the size of the patient calculated by another MLM

  result.bmi := weight / (size ** 2); // calculation of BMI
  age := currenttime - birth; // calculation of AGE

  // classification - the classification is only valid for patients older than 19
  if the age is less than 19 years then result.classification := null;
  elseif the result.bmi is less than 18.5 then result.classification := localized 'under';
  elseif the result.bmi is less than 25 then result.classification := null;
  else let the result.classification be localized 'over';
  endif;

  result.bmi := result.bmi formatted with localized 'msg'; // construct the localized message

  if (time of weight) is before (currenttime - 6 months) then
    conclude false; //no bmi calculation if the latest measure was 6 months ago
  else
    conclude result.classification is present ; // if there is a classification, execute the action slot
  endif;

;;
```

Sample MLM (cont.)

```
  action:

    write result.bmi || result.classification || "."; // return result

    return result;
  ;;
  urgency: ;;
  resources:
    default: de;;
    language: en
      'msg' : "The patient's BMI %.1f is not in the normal range and is classified as ";
      'under' : "Underweight";
      'over' : "Overweight"
    ;;
    language: de
      'msg' : "Der BMI %.1f des Patienten ist nicht im normalen Bereich und wird klassifiziert als ";
      'under' : "Untergewicht";
      'over' : "Übergewicht"
    ;;
end:
```

Arden Syntax – Fundamentals III

- Data types
- Statements, expressions (assignments, loops, variables, constants, objects)
- Operators
    - List operators
    - Logical operators
    - Comparison operators
    - String operators
    - Arithmetic operators
    - Temporal operators
    - Aggregation operators
    - Time and object operators

Primary Time

- In addition to its value part each data value has a **primary time** part and an applicability
- Primary time represents the value part's time of creation or measurement
- By default, primary time is `null`
- Can be accessed using the `time` operator

```
2011-03-15T00:00:00 := 2 days AFTER 2011-03-13T00:00:00
```

- Database query results should contain both, the value and the primary time
  - Might be the time when a blood test was drawn from the patient
  - Might be the time when a medication order was placed
  - Which time of a database entry is taken as primary time is left to the used Arden Syntax implementation

History

- A first draft of the standard was prepared at a meeting at the Arden Home-stead, New York, in 1989. Arden Syntax was previously adopted as a standard by the American Society for Testing and Materials (ASTM) as document E 1460, under subcommittee E31.15 Health Knowledge Representation.

- 1992: Arden Syntax version 1.0
- 1998: sponsorship moved to HL7 International (Arden Syntax Work Group)
- 1999: Arden Syntax version 2.0 adopted by HL7 and the American National Standards Institute (ANSI)
- 2014: Arden Syntax version 2.10

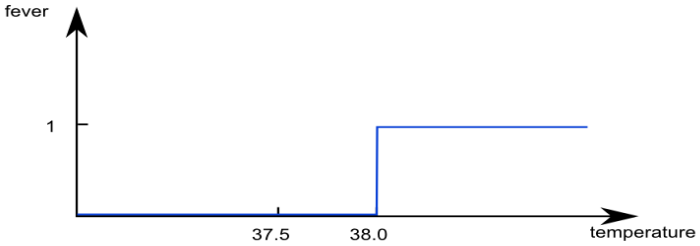
History

Version	Year	Important changes
2.1	2002	new string operators; reserved word “currenttime” returns the system time
2.5	2005	object capabilities: create and edit objects; XML representation of MLMs (except logic, action and data slot)
2.6	2007	UNICODE encoding; additional resources category to define text resources for specific languages; time-of-day and day-of-week data types; “localized” operator to access texts in specific languages
2.7	2008	enhanced assignment statement; extended “new” operator to allow easy and flexible object instantiation
2.8	2012	additional operators for list manipulation; operators to manipulate parts of given date and time values; switch statements; keyword “breakloop” for aborting a loop; number of editorial corrections
2.9	2013	fuzzification: fuzzy data types and fuzzy sets; adjustment of all available operators to be able to handle fuzzy data types
2.10	2014	XML representation of whole MLMs (including logic, action and data slot)

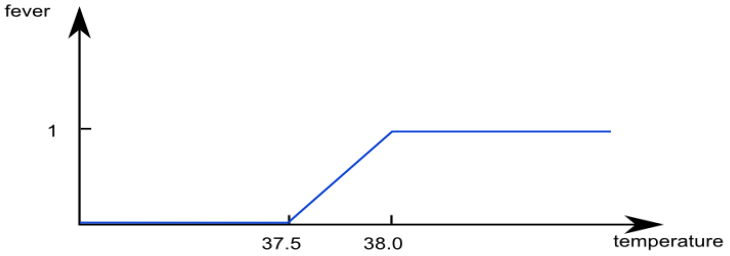
Fuzzy Arden Syntax

Fuzzy Sets – Background I

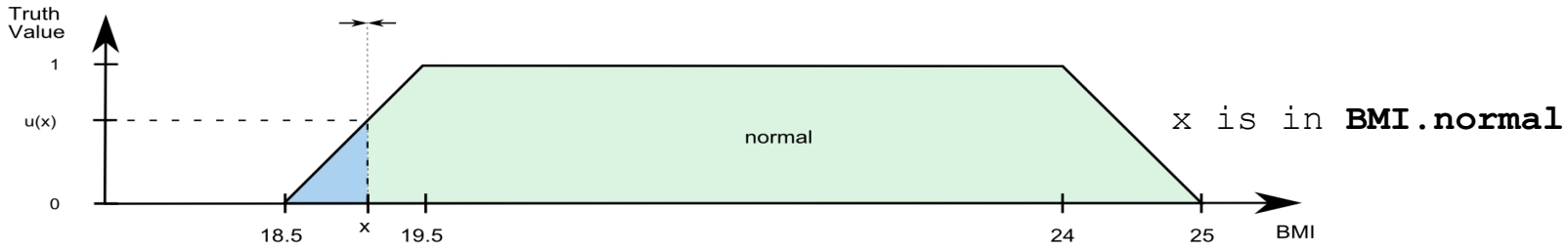
- **Crisp** border
  - Defines a **sharp** border
  - Checking if a given measurement is greater or less than the defined crisp border results in either true or false
  - Borderline cases are not detected



- **Fuzzified** border
  - Defines a **gradual** border
  - Checking if a given measurement is greater or less than the defined fuzzified border results in a truth value between 0 and 1
  - Borderline cases are detected
  - Weighted results for borderline cases, all other are as usual

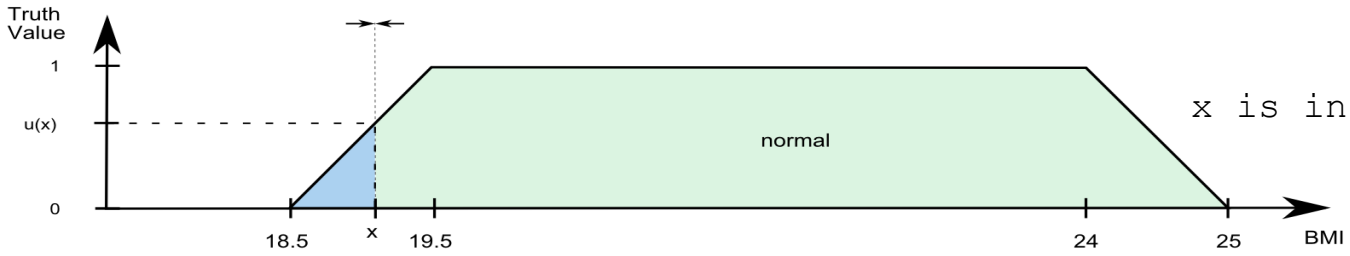


Fuzzy Sets – Background II



- Function that maps a given data value to a truth value between 0 and 1
- A **fuzzy set** represents a linguistic/clinical concept with fuzzy (non-sharp) boundaries

Fuzzy Sets



- Definition of a fuzzy set

```
Fuzzyset_u := FUZZY SET (18.5,0), (19.5,1), (24,1), (25,0);
Fuzzyset_v := 7 fuzzified by 2;
```

- Fuzzy set based on other data types

```
Fuzzyset_duration := FUZZY SET (3 days,0), (10 days,1), (20 days,1), (25 days,0);
simple := 2009-10-10 fuzzified by 12 hours;
complex := FUZZY SET (2009-10-10,0), (2009-10-11,1), (2009-11-10,1), (2009-
-  11-11,0);
```

Fuzzy Sets – Example I

- **Usual** Arden Syntax

```
fever_limit := 38;
temperature := 37.9;

message := "patient has no fever";
IF temperature > fever_limit THEN
   message := "patient has fever";
END IF
```

  - Result message: “patient has no fever”
  - Borderline case is not detected

- **Fuzzy** Arden Syntax

```
fever_limit := FUZZY SET (37.5,0), (38,1);
temperature := 37.9;

message := "patient has no fever";
IF temperature > fever_limit THEN
   message := "patient has fever";
END IF
```

  - Result message: “patient has fever” (with applicability 0.8)

Applicability

- Arden Syntax contains two types of fuzziness:
  - Data types: for explicit calculations e.g., truth value, fuzzy set
  - Applicability: for weighting MLM evaluation and weighting of branches

- All simple data types are endowed with information concerning the degree of **applicability**

- Stores a truth value that refers to the degree to which it is reasonable to use the value of a variable

- Default applicability is 1 and the applicability is never null

- Can be accessed using the `applicability` operator

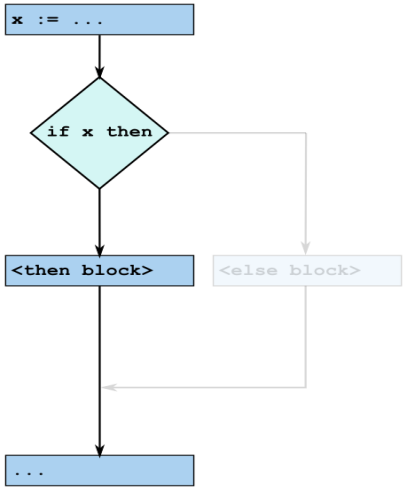
- If-then statements with a condition that evaluates to a truth value [0,1] result in a split of the MLM execution
  - Each branch will be executed under corresponding applicability
  - The applicability is implicit attached to each variable of the branch

Statements – If-Then-ElseIf – Fuzzy Condition

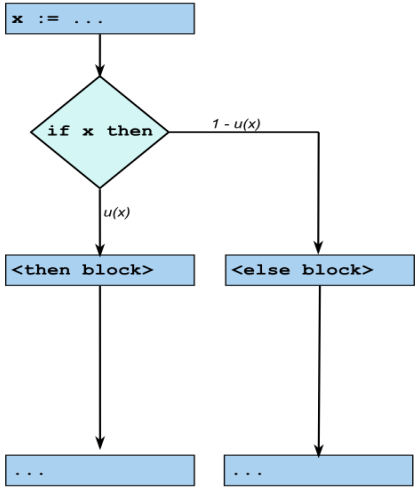
Source

```
maintenance: [...]
knowledge: [...]
logic:
 //define linguistic variable BMI
 [...]
 myBMI := 24.8;
 x := myBMI <= BMI.overweight;
 if x then
   // this branch is executed
   // with applicability 0.8
   <then_block>
 else
   // this branch is executed
   // with applicability 0.2
   <else_block>
 endif;
[...]
end:
```

Arden Syntax

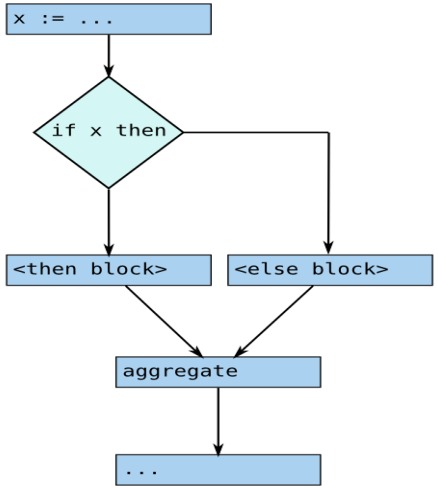


Fuzzy Arden Syntax



Statements – If-Then-Aggregate

```
if x then
   <then_block>
else
   <else_block>
endif AGGREGATE;
```



- Combination of the variable values in each execution branch according to their applicability
- Aggregations are common in fuzzy control

ArdenML

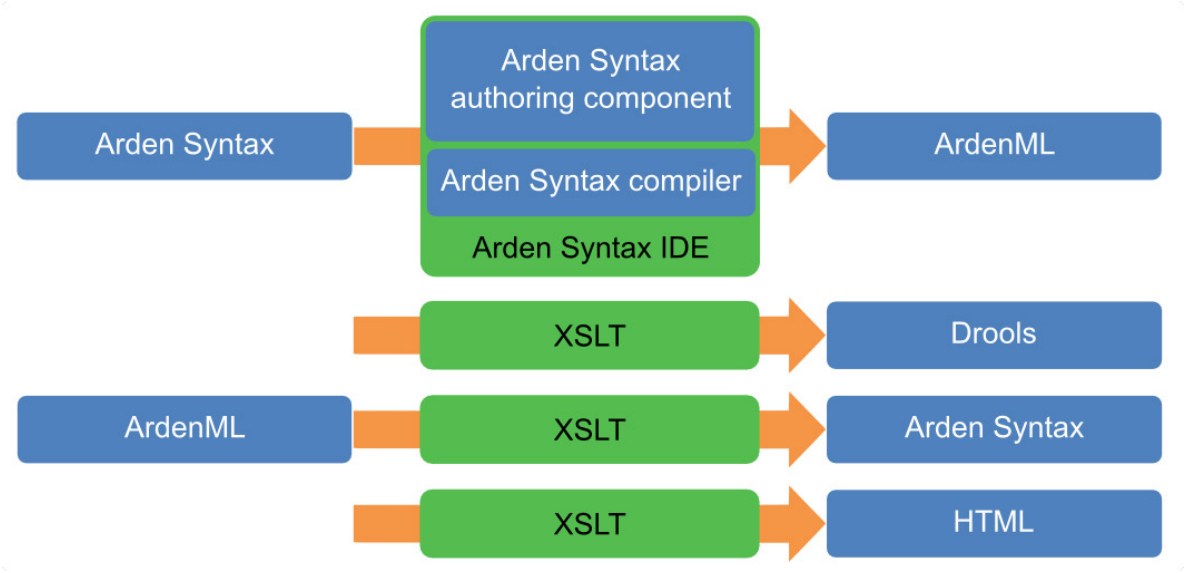
ArdenML: Objectives and applications

- Provide a complete XML schema for version 2.10 of the Arden Syntax to express MLMs in XML
- Thus, Arden Syntax is now compatible with all other HL7 standards based on XML (HL7 version 3, VmR, and others)
- Further benefit: To be able to use available XML tools

ArdenML: Example

```
<Library>
    <Purpose>Test</Purpose>
    <Explanation></Explanation>
    <Keywords></Keywords>
</Library>
<Knowledge>
    <Type>data_driven</Type>
    <Data></Data>
    <Evoke></Evoke>
    <Logic>
        <Assignment>
            <Identifier var='var1' />
            <Assigned>
                <Value otype='time'>1990-03-15T15:00:00</Value>
            </Assigned>
        </Assignment>
        <Assignment>
            <Identifier var='res1' />
            <Assigned>
                <ReplaceYearWith>
                    <Identifier var='var1' />
                    <Value otype='number'>2011</Value>
                </ReplaceYearWith>
            </Assigned>
        </Assignment>
        <Assignment>
            <Identifier var='res2' />
            <Assigned>
                <ReplaceYearWith>
                    <Identifier var='var1' />
                    <List>
                        <Value otype='number'>2011</Value>
                        <Value otype='number'>2010</Value>
                    </List>
                </ReplaceYearWith>
            </Assigned>
```

Cross compilation/transformation of Arden Syntax to/from ArdenML



Integration

How to execute MLMs

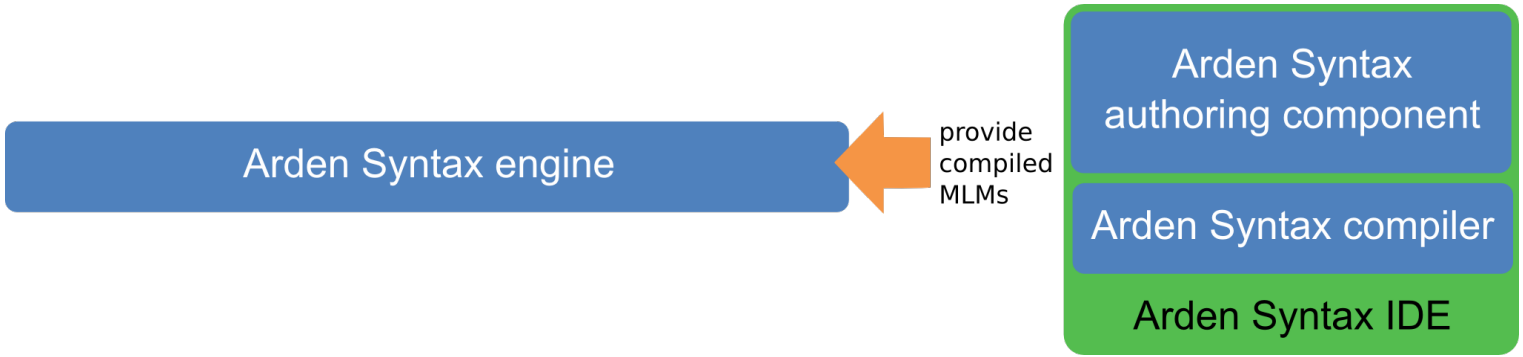
- **MLM calls:** When the MLM call statement is executed, the current MLM is interrupted, and the named MLM is called; parameters are passed to the named MLM

```
/* Define find_allergies MLM */
find_allergies := MLM 'find_allergies';
(allergens, reactions):= call find_allergies;
```

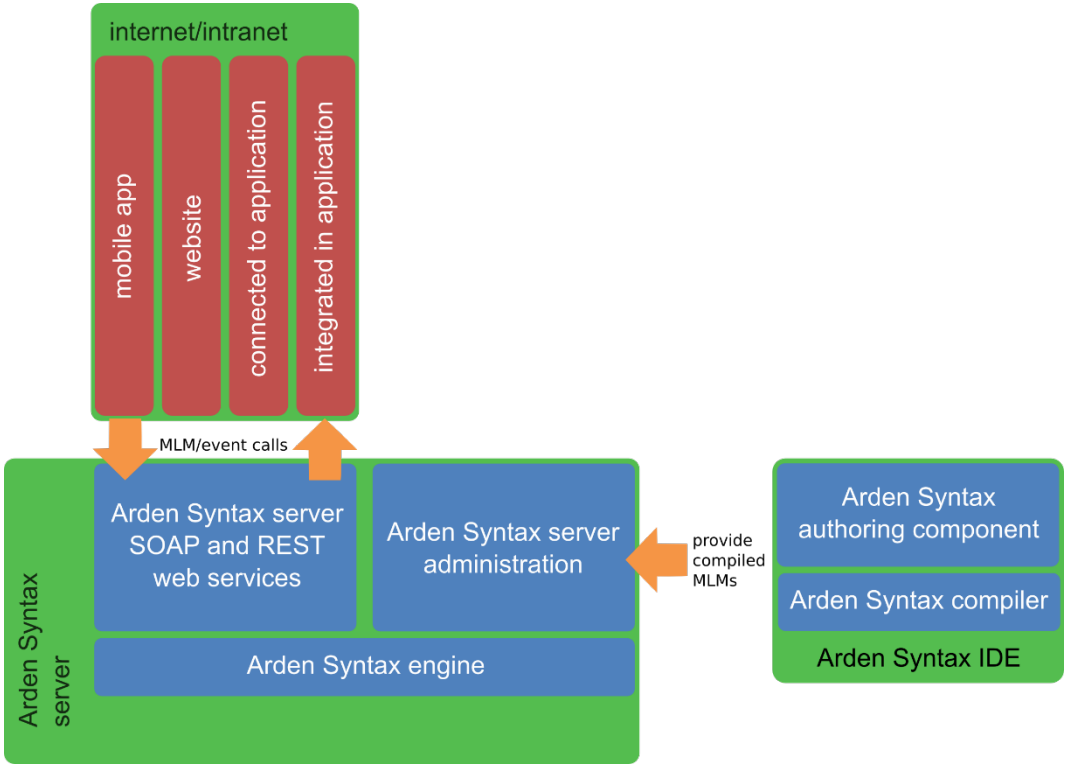
- **Event calls:** When the event call statement is executed, the current MLM is interrupted, and all the MLMs whose evoke slots refer to the named event are executed; parameters are passed to the named MLMs

```
allergy_found := EVENT {allergy found};
reactions := call allergy_found;
```

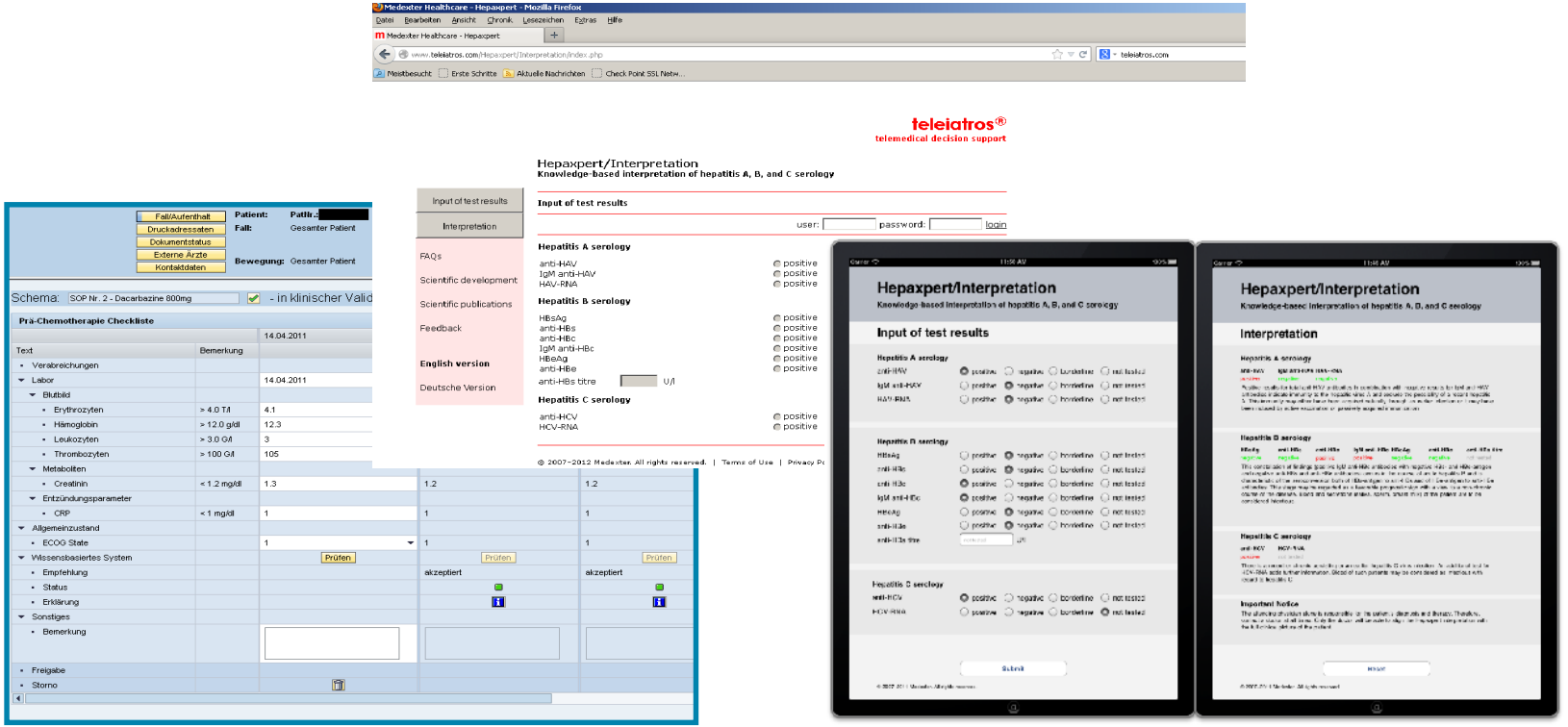
How to execute MLMs – Arden Syntax Engine



How to execute MLMs – Web Service Interfaces



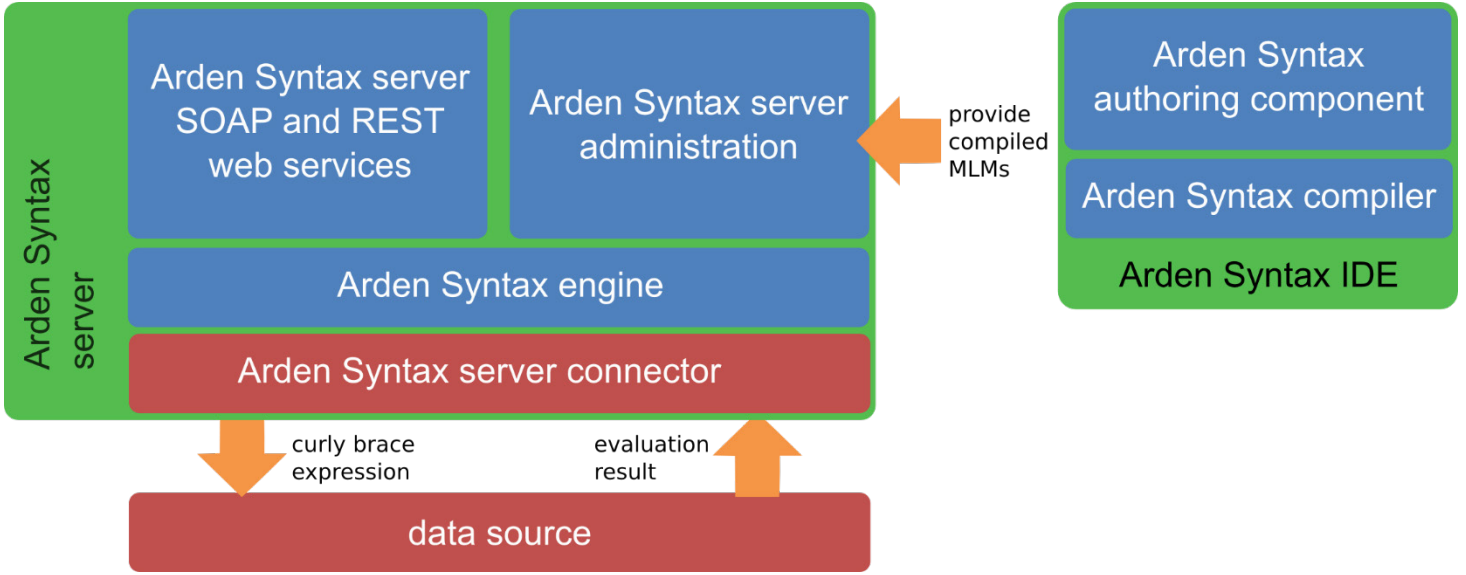
How to execute MLMs – Web Service Usage



How to get data into MLMs

- MLM and event calls
  - Provide data to an other MLM
  - Read data provided to the actual MLM
  - Return data to calling MLM or instance
- Curly brace expressions
  - Read data from external data sources
  - Write data to external data sources
  - Call external applications or interfaces

How to get data into MLMs – Curly Brace Expressions



Types of Integration I

I. MLM/event calls together with data
   - through web-services (intranet/Internet)

Types of Integration II

II.

MLM/event calls
- through web-services

data access from inside MLMs
- through server connector as
  - + … {web-services}
  - + … {SQL statements}
  - + … {…}

Types of Integration III

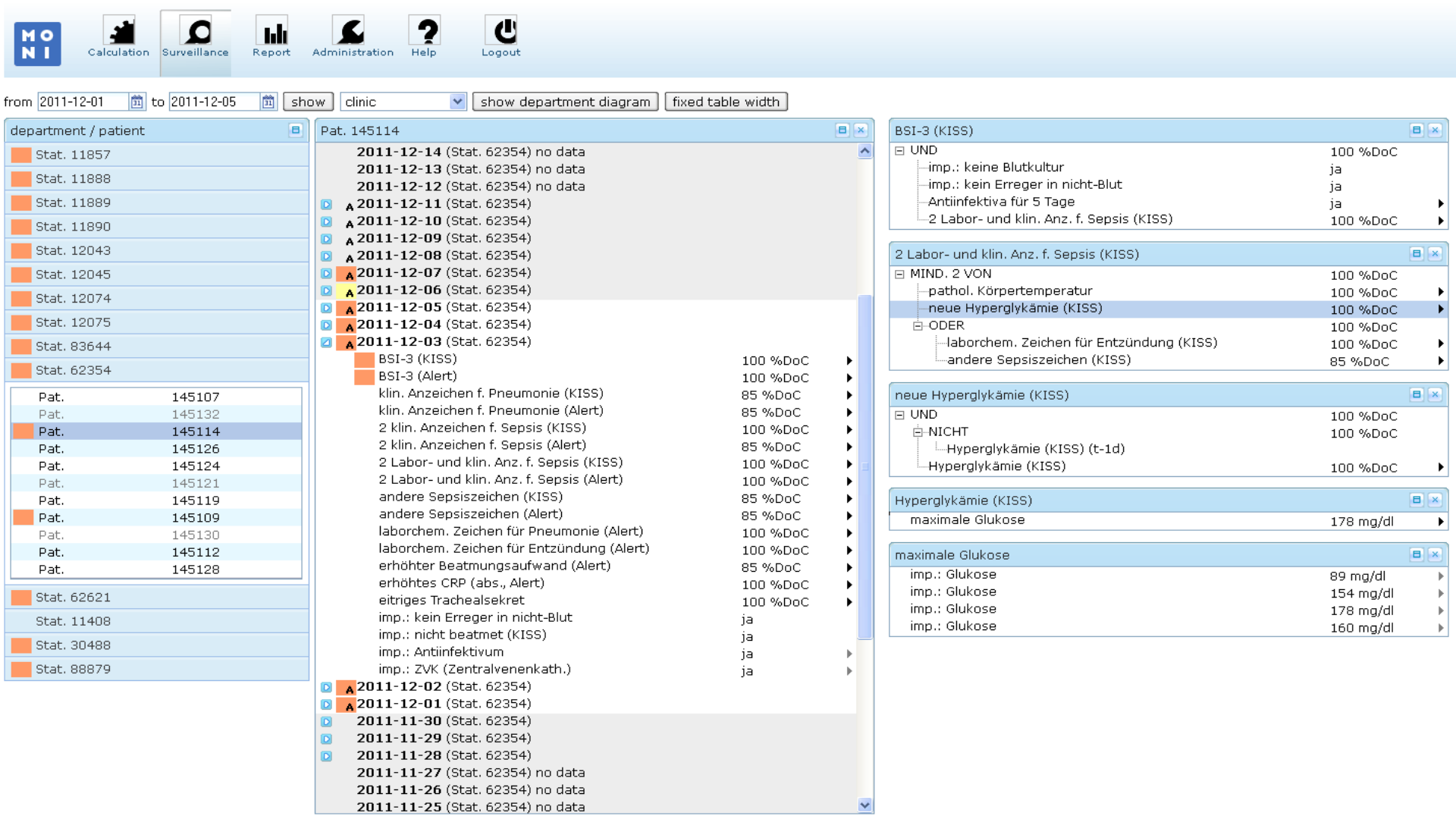
III.

Data warehouse + Arden Syntax server = autonomous CDS system

- data provided through HL7/XML/batch/… communication
- full process control (MLM triggering)
- additional analytics, reporting, benchmarking
- full legal control (legal obligation to retain data, burden of proof)

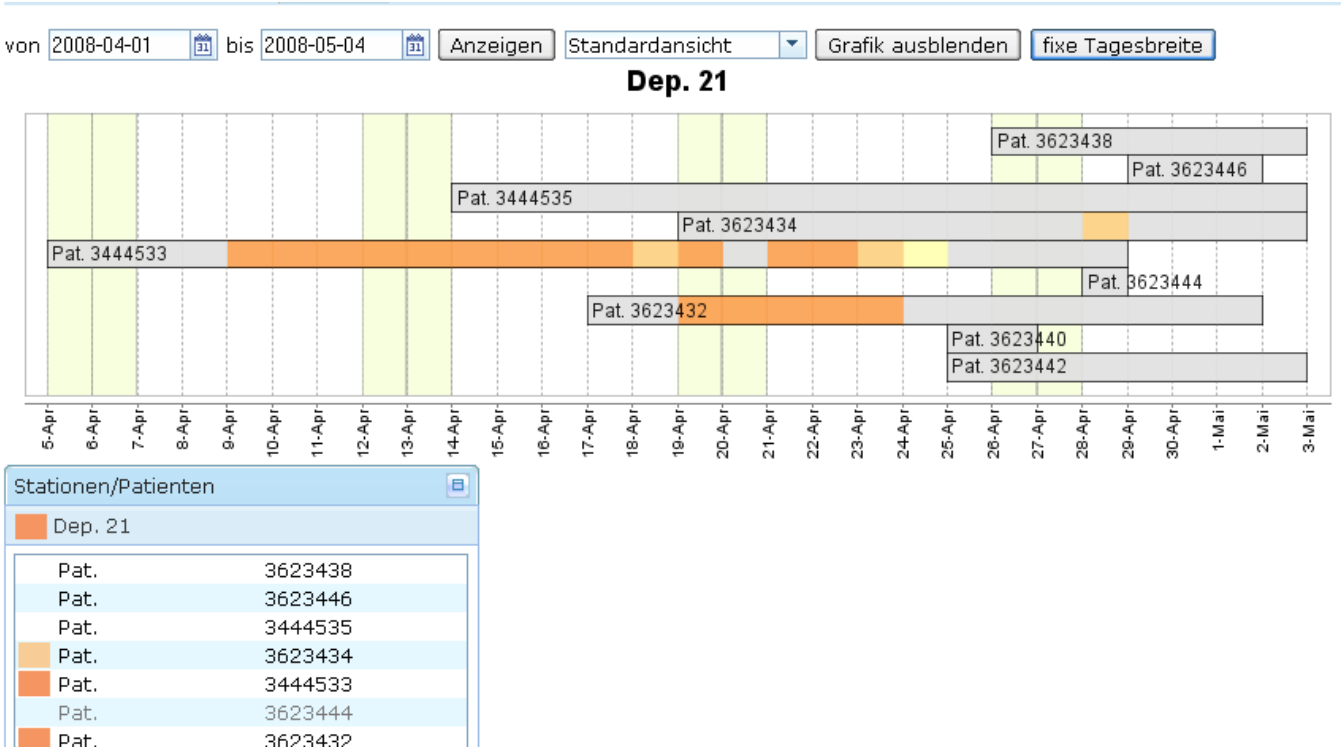
Clinical decision support with Arden Syntax

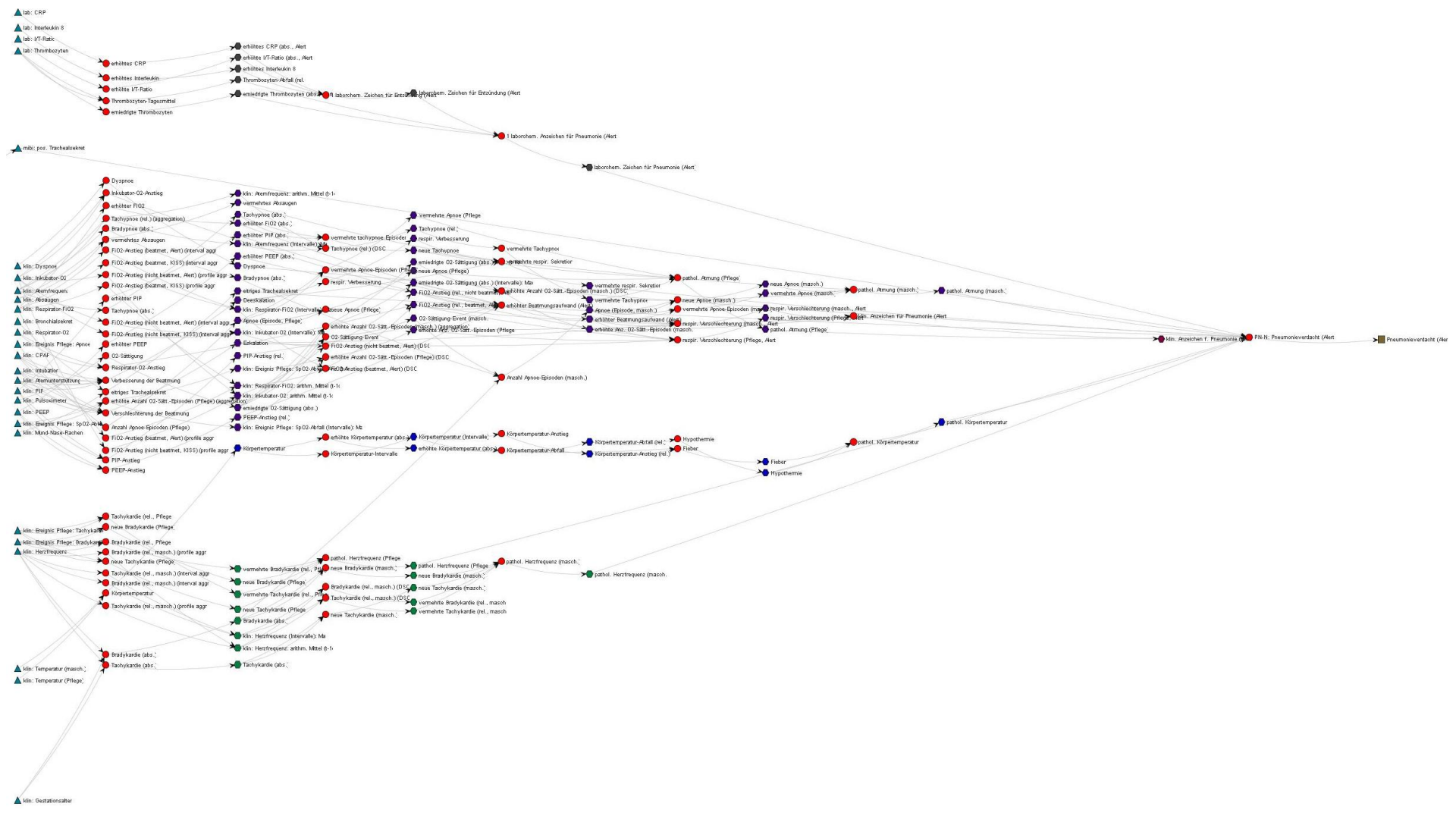
- CDS platforms
  - based on Arden Syntax and Fuzzy Arden Syntax
    - with data (sometimes) and knowledge services center and extended interoperability (web services, XML data interfaces, libraries, HL7)
- integrated into or interconnected with
  - PDMSs (ICCA by Philips, MetaVision by iMDsoft)
    - Monitoring, reporting, and benchmarking of ICU-acquired infections (ICUs and NICUs)
  - ICM (by Dräger)
    - ICU decision support modules (Universitätsklinikum Erlangen)
  - i.s.h.med HIS and Soarian HIS (by Siemens AG)
    - dosing of immunosuppressive drugs for kidney transplant patients
    - prediction of metastases in melanoma patients
    - standard operating procedures for chemotherapy treatment of melanoma patients
    - hepatitis serology test interpretation
  - medico//s HIS (by Siemens AG)
    - laboratory-based clinical reminders
  - Epic
    - clinical decision support
  - VistA HIS (by Department of Veterans Affairs)
    - service-oriented, standards-based CDS (clinical reminders and patient report cards)
  - Monitoring adverse drug events (project with Salzburger Universitätsklinikum)
  - Teleiatros, iPhone, iPad
    - remote CDS, mHealth


MONI
Calculation
Surveillance
Report
Administration
Help
Logout
from 2011-12-01 to 2011-12-05 show clinic show department diagram fixed table width
department / patient
Stat. 11857
Stat. 11888
Stat. 11889
Stat. 11890
Stat. 12043
Stat. 12045
Stat. 12074
Stat. 12075
Stat. 83644
Stat. 62354
Pat. 145107
Pat. 145132
Pat. 145114
Pat. 145126
Pat. 145124
Pat. 145121
Pat. 145119
Pat. 145109
Pat. 145130
Pat. 145112
Pat. 145128
Stat. 62621
Stat. 11408
Stat. 30488
Stat. 88879
Pat. 145114
2011-12-14 (Stat. 62354) no data
2011-12-13 (Stat. 62354) no data
2011-12-12 (Stat. 62354) no data
2011-12-11 (Stat. 62354)
2011-12-10 (Stat. 62354)
2011-12-09 (Stat. 62354)
2011-12-08 (Stat. 62354)
2011-12-07 (Stat. 62354)
2011-12-06 (Stat. 62354)
2011-12-05 (Stat. 62354)
2011-12-04 (Stat. 62354)
2011-12-03 (Stat. 62354)
BSI-3 (KISS) 100 %DoC
BSI-3 (Alert) 100 %DoC
klin. Anzeichen f. Pneumonie (KISS) 85 %DoC
klin. Anzeichen f. Pneumonie (Alert) 85 %DoC
2 klin. Anzeichen f. Sepsis (KISS) 100 %DoC
2 klin. Anzeichen f. Sepsis (Alert) 85 %DoC
2 Labor- und klin. Anz. f. Sepsis (KISS) 100 %DoC
2 Labor- und klin. Anz. f. Sepsis (Alert) 100 %DoC
andere Sepsiszeichen (KISS) 85 %DoC
andere Sepsiszeichen (Alert) 85 %DoC
laborchem. Zeichen für Pneumonie (Alert) 100 %DoC
laborchem. Zeichen für Entzündung (Alert) 100 %DoC
erhöhter Beatmungsaufwand (Alert) 85 %DoC
erhöhtes CRP (abs., Alert) 100 %DoC
eitriges Trachealsekret 100 %DoC
imp.: kein Erreger in nicht-Blut ja
imp.: nicht beatmet (KISS) ja
imp.: Antiinfektivum ja
imp.: ZVK (Zentralvenenkath.) ja
2011-12-02 (Stat. 62354)
2011-12-01 (Stat. 62354)
2011-11-30 (Stat. 62354)
2011-11-29 (Stat. 62354)
2011-11-28 (Stat. 62354)
2011-11-27 (Stat. 62354) no data
2011-11-26 (Stat. 62354) no data
2011-11-25 (Stat. 62354) no data
BSI-3 (KISS)
UND 100 %DoC
imp.: keine Blutkultur ja
imp.: kein Erreger in nicht-Blut ja
Antiinfektiva für 5 Tage ja
2 Labor- und klin. Anz. f. Sepsis (KISS) 100 %DoC
2 Labor- und klin. Anz. f. Sepsis (KISS)
MIND. 2 VON 100 %DoC
pathol. Körpertemperatur 100 %DoC
neue Hyperglykämie (KISS) 100 %DoC
ODER 100 %DoC
laborchem. Zeichen für Entzündung (KISS) 100 %DoC
andere Sepsiszeichen (KISS) 85 %DoC
neue Hyperglykämie (KISS)
UND 100 %DoC
NICHT 100 %DoC
Hyperglykämie (KISS) (t-1d)
Hyperglykämie (KISS) 100 %DoC
Hyperglykämie (KISS)
maximale Glukose 178 mg/dl
maximale Glukose
imp.: Glukose 89 mg/dl
imp.: Glukose 154 mg/dl
imp.: Glukose 178 mg/dl
imp.: Glukose 160 mg/dl

Moni output

Section of Moni screenshot for one ICU: Colors indicate patients with infection episodes, where change in color means change in data-definition compatibility




lab: CRP
lab: Interleukin 8
lab: I/T-Ratio
lab: Thrombozyten
erhöhtes CRP
erhöhtes Interleukin
erhöhte I/T-Ratio
Thrombozyten-Tagesmittel
erniedrigte Thrombozyten
erhöhtes CRP (abs., Alert
erhöhte I/T-Ratio (abs., Alert
erhöhtes Interleukin 8
Thrombozyten-Abfall (rel.
erniedrigte Thrombozyten (abs.)
laborchem. Zeichen für Entzündung (Alert
laborchem. Zeichen für Entzündung (Alert
laborchem. Anzeichen für Pneumonie (Alert
mibi: pos. Trachealsekret
laborchem. Zeichen für Pneumonie (Alert
Dyspnoe
Inkubator-O2-Anstieg
erhöhter FiO2
Tachypnoe (rel.) (aggregation)
Bradypnoe (abs.)
vermehrtes Absaugen
FiO2-Anstieg (beatmet, Alert) (interval aggr
FiO2-Anstieg (beatmet, KISS) (interval aggr
FiO2-Anstieg (nicht beatmet, Alert) (profile aggr
FiO2-Anstieg (beatmet, KISS) (profile aggr
erhöhter PIP
Tachypnoe (abs.)
FiO2-Anstieg (nicht beatmet, Alert) (interval aggr
FiO2-Anstieg (nicht beatmet, KISS) (interval aggr
erhöhter PEEP
O2-Sättigung
Respirator-O2-Anstieg
Verbesserung der Beatmung
eitriges Trachealsekret
erhöhte Anzahl O2-Sätt.-Episoden (Pflege) (aggregation)
Verschlechterung der Beatmung
Anzahl Apnoe-Episoden (Pflege)
FiO2-Anstieg (beatmet, Alert) (profile aggr
FiO2-Anstieg (nicht beatmet, KISS) (profile aggr
PIP-Anstieg
PEEP-Anstieg
klin.: Dyspnoe
klin.: Inkubator-O2
klin.: Atemfrequenz
klin.: Absaugen
klin.: Respirator-FiO2
klin.: Bronchialsekret
klin.: Respirator-O2
klin.: Ereignis Pflege: Apnoe
klin.: CPAP
klin.: Intubation
klin.: Atemunterstützung
klin.: PIP
klin.: Pulsoximeter
klin.: PEEP
klin.: Ereignis Pflege: SpO2-Abfall
klin.: Mund-Nase-Rachen
klin.: Atemfrequenz: arithm. Mittel (t-1
vermehrtes Absaugen
Tachypnoe (abs.)
erhöhter FiO2 (abs.)
erhöhter PIP (abs.)
klin.: Atemfrequenz (Intervalle): Ma
erhöhter PEEP (abs.)
Dyspnoe
Bradypnoe (abs.)
eitriges Trachealsekret
Deeskalation
klin.: Respirator-FiO2 (Intervalle): Ma
Apnoe (Episode, Pflege)
Exkalation
klin.: Inkubator-O2 (Intervalle): Ma
PIP-Anstieg (rel.)
klin.: Ereignis Pflege: SpO2-Abfall (Intervalle): Ma
PEEP-Anstieg (rel.)
klin.: Ereignis Pflege: SpO2-Abfall (Intervalle): Ma
Körpertemperatur
klin.: Respirator-FiO2: arithm. Mittel (t-1
klin.: Inkubator-O2: arithm. Mittel (t-1
erniedrigte O2-Sättigung (abs.)
vermehrte tachypnoe Episoden
Tachypnoe (rel.) (DSC
vermehrte Apnoe-Episoden (Pflege)
respir. Verbesserung
neue Apnoe (Pflege)
erhöhte Anzahl O2-Sätt.-Episoden (masch.)
O2-Sättigung-Event
FiO2-Anstieg (nicht beatmet, Alert) (DSC
erhöhte Anzahl O2-Sätt.-Episoden (Pflege) (DSC
FiO2-Anstieg (beatmet, Alert) (DSC
erhöhte Körpertemperatur (abs.)
Körpertemperatur-Intervalle
vermehrte Apnoe (Pflege
Tachypnoe (rel.)
respir. Verbesserung
neue Tachypnoe
erniedrigte O2-Sättigung (abs.)
erniedrigte O2-Sättigung (abs.) (Intervalle): Ma
FiO2-Anstieg (rel., nicht beatmet, Alert)
FiO2-Anstieg (rel., beatmet, Alert)
O2-Sättigung-Event (masch.)
erhöhte Anz. O2-Sätt.-Episoden (Pflege
erhöhte Körpertemperatur (abs.)
vermehrte respir. Sekretion
vermehrte Tachypnoe
neue Apnoe (masch.)
Apnoe (Episode, masch.)
erhöhte Anz. O2-Sätt.-Episoden (masch.
Anzahl Apnoe-Episoden (masch.)
Körpertemperatur-Anstieg
Körpertemperatur-Abfall
pathol. Atmung (Pflege
vermehrte respir. Sekretion
vermehrte Tachypnoe
neue Apnoe (masch.)
vermehrte Apnoe-Episoden (masch.)
erhöhter Beatmungsaufwand (Alert
respir. Verschlechterung (masch., Alert
respir. Verschlechterung (Pflege, Alert
Körpertemperatur-Abfall (rel.)
Körpertemperatur-Anstieg (rel.)
neue Apnoe (masch.)
vermehrte Apnoe (masch.
pathol. Atmung (masch.)
respir. Verschlechterung (masch., Alert
respir. Verschlechterung (Pflege, Alert
pathol. Atmung (Pflege)
Hypothermie
Fieber
pathol. Atmung (masch.)
pathol. Atmung (masch.)
klin.: Anzeichen f. Pneumonie (Alert
Fieber
Hypothermie
pathol. Körpertemperatur
pathol. Körpertemperatur
PN-N: Pneumonieverdacht (Alert
Pneumonieverdacht (Aler
klin.: Ereignis Pflege: Tachykardie
klin.: Ereignis Pflege: Bradykardie
klin.: Herzfrequenz
Tachykardie (rel., Pflege
neue Bradykardie (Pflege
Bradykardie (rel., Pflege
Bradykardie (rel., masch.) (profile aggr
neue Tachykardie (Pflege
Tachykardie (rel., masch.) (interval aggr
Bradykardie (rel., masch.) (interval aggr
Körpertemperatur
Tachykardie (rel., masch.) (profile aggr
Bradykardie (abs.)
Tachykardie (abs.)
vermehrte Bradykardie (rel., Pflege
neue Bradykardie (Pflege
vermehrte Tachykardie (rel., Pflege
neue Tachykardie (Pflege
Bradykardie (abs.)
klin.: Herzfrequenz (Intervalle): Ma
klin.: Herzfrequenz: arithm. Mittel (t-1
Tachykardie (abs.)
pathol. Herzfrequenz (Pflege
neue Bradykardie (masch.)
Bradykardie (rel., masch.) (DSC
Tachykardie (rel., masch.) (DSC
neue Tachykardie (masch.)
pathol. Herzfrequenz (Pflege
neue Bradykardie (masch.)
neue Tachykardie (masch.)
vermehrte Bradykardie (rel., masch
vermehrte Tachykardie (rel., masch
pathol. Herzfrequenz (masch.)
pathol. Herzfrequenz (masch.
klin.: Temperatur (masch.)
klin.: Temperatur (Pflege)
klin.: Gestationsalter

Arden Syntax—integration of software

III.

Data warehouse + Arden Syntax server = autonomous CDS system

- data provided through HL7/XML/batch/… communication
- full process control (MLM triggering)
- additional analytics, reporting, benchmarking
- full legal control (legal obligation to retain data, burden of proof)

First study:

⇒ 99 ICU patient admissions; 1007 patient days

HAI episodes correctly / falsely identified or missed by Moni-ICU

	episode present "gold standard" (n= 19)	episode absent "gold standard" (n= 78)
episode present "Moni-ICU"	16 (84%)	0 (0%)
episode absent "Moni-ICU"	3 (16%)	78 (100%)

Time expenditure for both surveillance techniques

	conventional surveillance	Moni-ICU surveillance
time spent	82.5 h (100%)	12.5 h (15.2%)

Blacky, A., Mandl, H., Adlassnig, K.-P. & Koller, W. (2011) Fully Automated Surveillance of Healthcare-Associated Infections with MONI-ICU – A Breakthrough in Clinical Infection Surveillance. Applied Clinical Informatics 2(3), 365–372.

Second study:

⇒ 93 ICU patient admissions; 882 patient days; 30 HAI episodes over complete or partial duration of stay; 76 stays with no HAI episodes

HAI episodes correctly / falsely identified or missed by Moni-ICU

		gold standard I+	*gold standard* I-
Moni-ICU	I+	26	1
	I-	4	75
		30	76

sensitivity = 87%

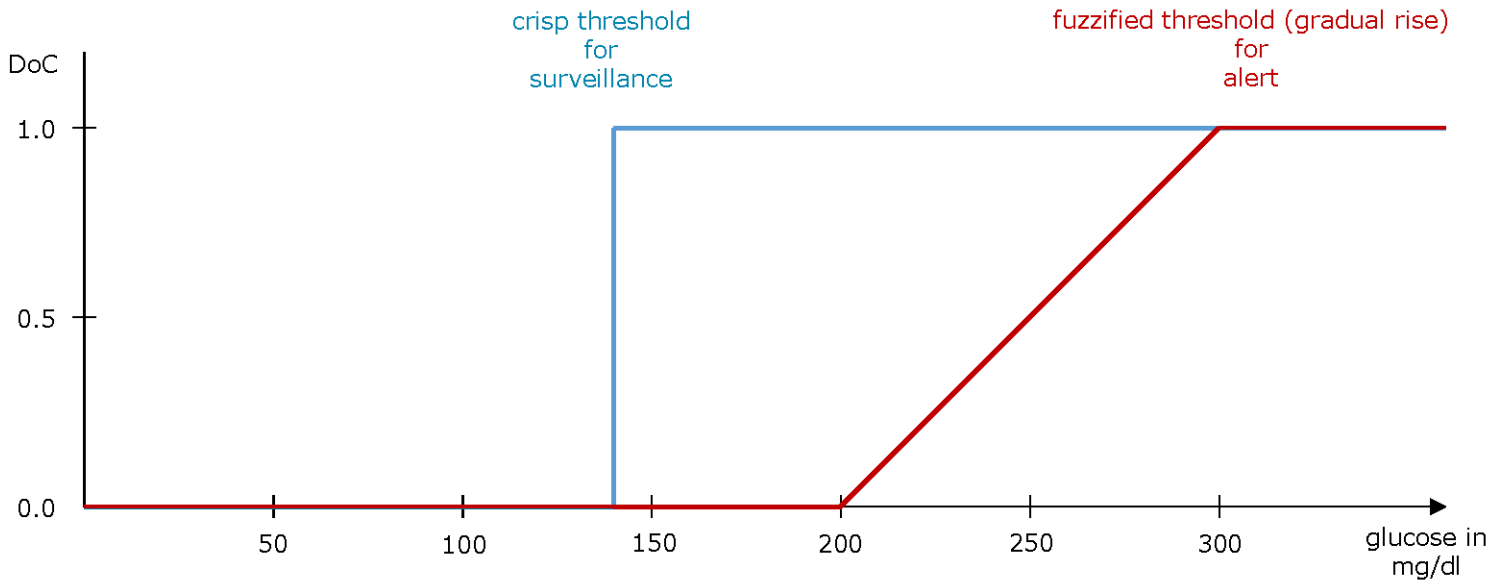
- 3 false-negative pneumonias + 1 false-negative CVC-related infection due to missing microbiology

specificity = 99%

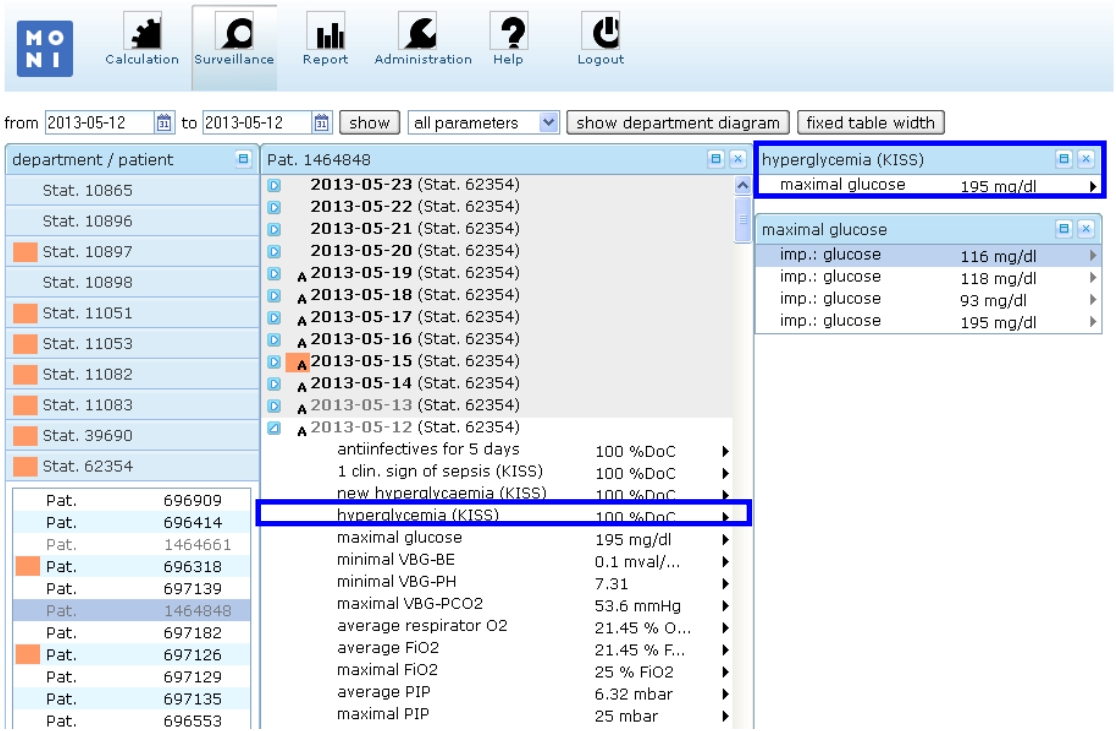
- 1 false-positive CVC-related infection because of a present concomitant leukemia (with leukocytosis)

De Bruin, J.S., Adlassnig, K.-P., Blacky, A., Mandl, H., Fehre, K. & Koller, W. (2013) Effectiveness of an Automated Surveillance System for Intensive Care Unit-Acquired Infections. Journal of the American Medical Informatics Association 20(2), 369–372.

Two different hyperglycemia definitions



Moni-NICU cockpit view



MEDIZINISCHE UNIVERSITÄT WIEN

Regel zur Interpretation von klinisch relevanten Befunden (Regelprämissen bilden Äquivalenzklassen)

REGEL 103:

WENN eine der folgenden 100 Kombinationen zutrifft

HBsAg	anti-HBs	anti-HBc	IgM-anti-HBc	HBeAg	anti-HBe
+ •	+	− ±	− ± •	+	− ± •
+ •	+	+ •	+ − ± •	+	+ − ± •

DANN

Das gleichzeitige Auftreten von HBe-Antigen und Anti-HBs-Antikörpern ist im natürlichen Verlauf einer Hepatitis-B-Virusinfektion ein seltenes Ereignis. Diese Befundkonstellation ist entweder auf (a) zirkulierende HBsAg-anti-HBs-Immunkomplexe, (b) auf eine Koinzidenz einer Hepatitis-B-Virusinfektion mit einer Hepatitis-B-Impfung oder Injektion von HB-Hyperimmunglobulin oder (c) eine Reinfektion mit einem Hepatitis-B-Virus mit unterschiedlichem HBsAg-Subtypus zurückzuführen. Blut und Sekrete (Speichel, Sperma, Muttermilch) solcher Patienten sind als infektiös anzusehen.

Interpretation of hepatitis serology test results

teleiatros®

Hepaxpert/Interpretation
Knowledge-based interpretation of hepatitis A, B, and C serology

Interpretation

Benutzer: mxt Logout

Hepatitis-A-Serologie

Anti-HAV	IgM-anti-HAV	HAV-RNA
positiv	nicht untersucht	nicht untersucht

Antikörper gegen das Hepatitis-A-Virus finden sich in drei unterschiedlichen Situationen: (a) bei rezenter Hepatitis-A-Virusinfektion (akute ikterische oder anikterische Hepatitis, stille Feiung oder Rekonvaleszenzstadium einer Hepatitis), (b) bei Immunität nach früherer Hepatitis-A-Virusinfektion oder (c) nach aktiver Impfung oder passiver Immunisierung mit Gammaglobulin.

Hepatitis-B-Serologie

HBsAg	Anti-HBs	Anti-HBc	IgM-anti-HBc
positiv	positiv	positiv	positiv
HBeAg	**Anti-HBe**	**Anti-HBs Titer**	
positiv	positiv	- - - U/l	

Das gleichzeitige Auftreten von HBe-Antigen und Anti-HBs-Antikörpern ist im natürlichen Verlauf einer Hepatitis-B-Virusinfektion ein seltenes Ereignis. Diese Befundkonstellation ist entweder auf (a) zirkulierende HBsAg-Anti-HBs-Immunkomplexe, (b) auf eine Koinzidenz einer Hepatitis-B-Virusinfektion mit einer Hepatitis-B-Impfung oder Injektion von HB-Hyperimmunglobulin oder (c) eine Reinfektion mit einem Hepatitis-B-Virus mit unterschiedlichem HBsAg-Subtypus zurückzuführen. Blut und Sekrete (Speichel, Sperma, Muttermilch) solcher Patienten sind als infektiös anzusehen.

Hepatitis-C-Serologie

Anti-HCV	HCV-RNA
positiv	negativ

Der erhobene Befund spricht für eine früher abgelaufene HCV-Infektion oder für eine Remission einer bestehenden HCV-Infektion. Bei klinischem Verdacht auf Hepatitis C sind Verlaufskontrollen indiziert. Das Blut solcher Personen ist hinsichtlich Hepatitis C als infektiös anzusehen.

Wichtiger Hinweis

Die Verantwortung für Diagnose und Therapie eines Patienten trägt ausschließlich der behandelnde Arzt. Konsultieren Sie daher immer einen Arzt. Nur dieser kann die Hepaxpert-Interpretation in Einklang mit dem gesamten klinischen Bild des Patienten bringen.

	Befund 02.05.2001 (09:46)	Vor-Befund	Referenzbereich und Einheit	
PROTEINDIAGNOSTIK				
CRP	61.5 ***		0.8-5.0	mg/l
HORMONE				
	Schilddrüsendiagnostik			
TSH	3.00		0.2-3.5	mU/l
INFEKTIONSSEROLOGIE				
HIV-Antikörper	Negativ			Negativ
HEPATITIS-SEROLOGIE				
Anti-HAV-IgM	Negativ			Negativ
Anti-HAV	**Positiv** *			Negativ
HBsAG	Negativ			
Anti-HBs	Negativ			
Anti-HBs (quant.)	1.42			U/l
Anti-HBc	Negativ			
Anti-HCV	Negativ			Negativ

test results

Medizin. Kommentar/Interpretation:

HEPATITIS-SEROLOGIE:

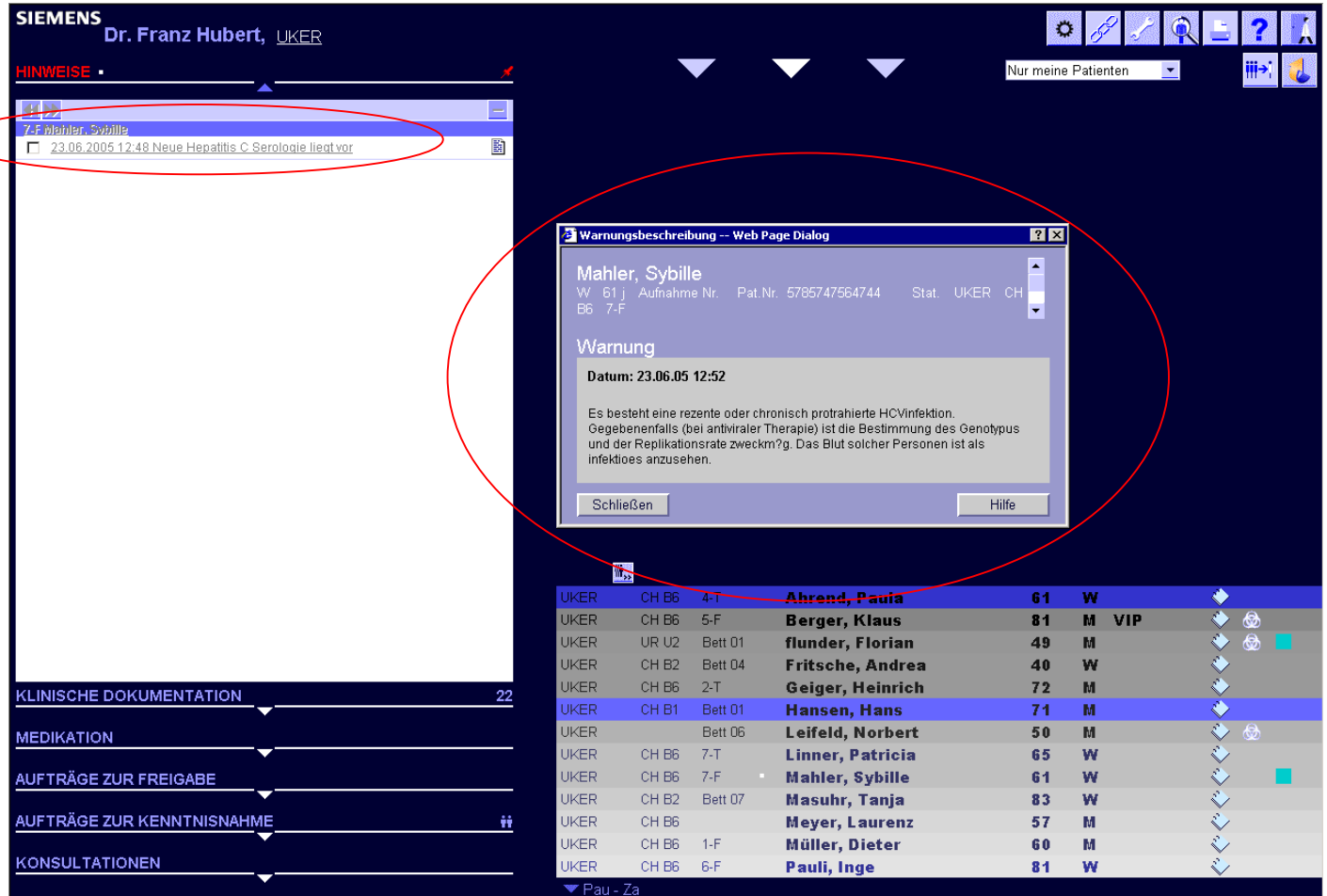
Positive Gesamtkörper (Anti-HAV) bei negativen IgM-anti-HAV Antikörpern beweisen Immunität gegen das Hepatitis-A-Virus und schließen eine rezente Hepatitis A aus. Diese Immunität kann entweder durch eine frühere Infektion natürlich erworben oder aber durch aktive Impfung oder passive Immunisierung induziert sein.

Anti-HBs Titer: 1 Units/Liter

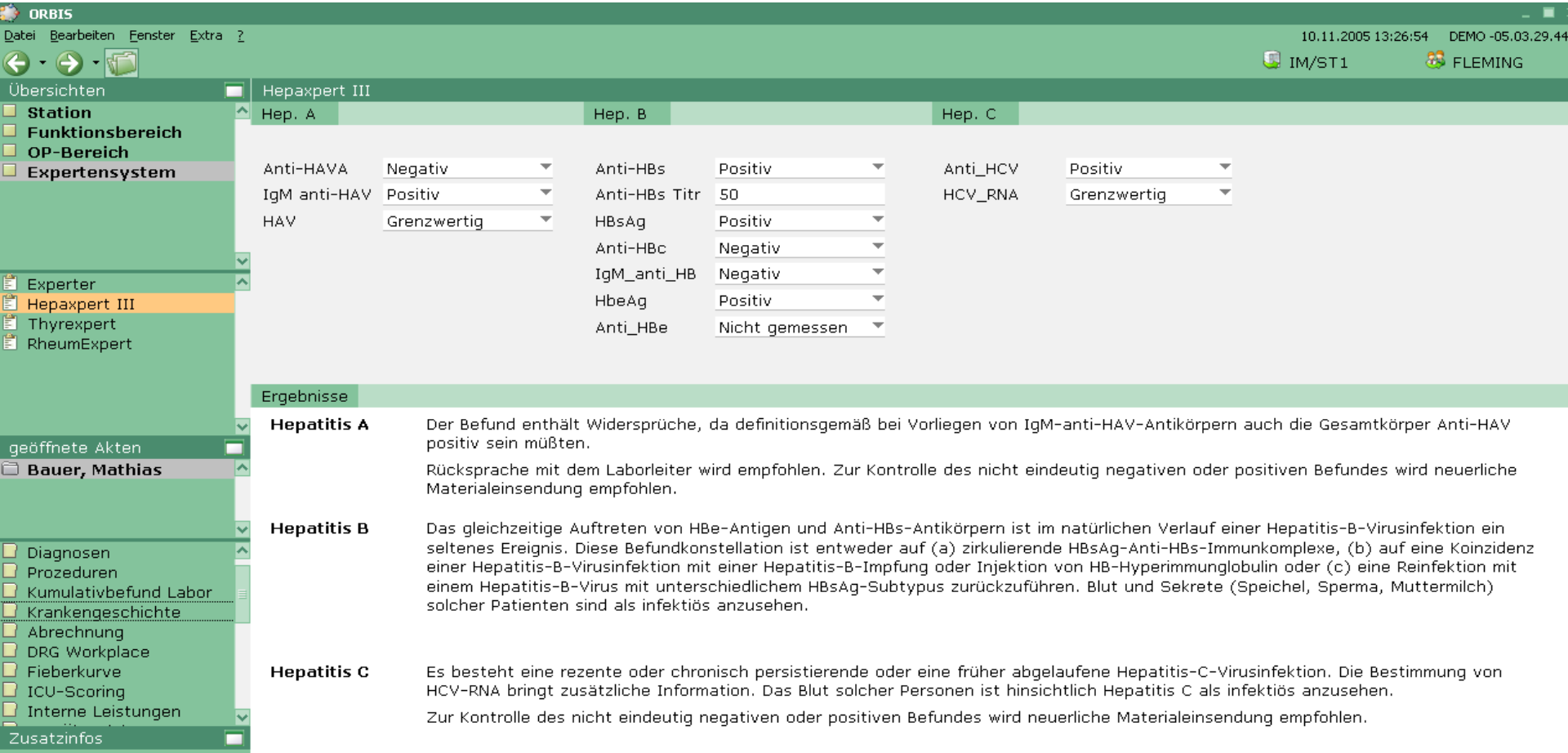
Eine bestehende oder frühere Hepatitis-B-Virusinfektion kann (mit Ausnahme des Inkubationsstadiums) ausgeschlossen werden. Es besteht keine Immunität gegen das Hepatitis-B-Virus. Das Blut kann hinsichtlich Hepatitis B als nicht infektiös angesehen werden. Impfempfehlung: Die Indikation zur Hepatitis-B-Impfung vorausgesetzt, soll in diesem Fall bei einem Ungeimpften die Grundimmunisierung (entsprechend dem Schema des jeweiligen Impfstoffes) durchgeführt und - zur Abschätzung der Immunantwort - 1-2 Monate nach der letzten Teilimpfung der Anti-HBs Titer bestimmt werden. Bei einem Geimpften mit abgeschlossener Grundimmunisierung soll unverzüglich eine Booster Injektion gegeben und - falls der Verdacht eines ælow responders Æ besteht - eine Titerkontrolle 2 Monate nach dem Booster erhoben werden.

interpretation

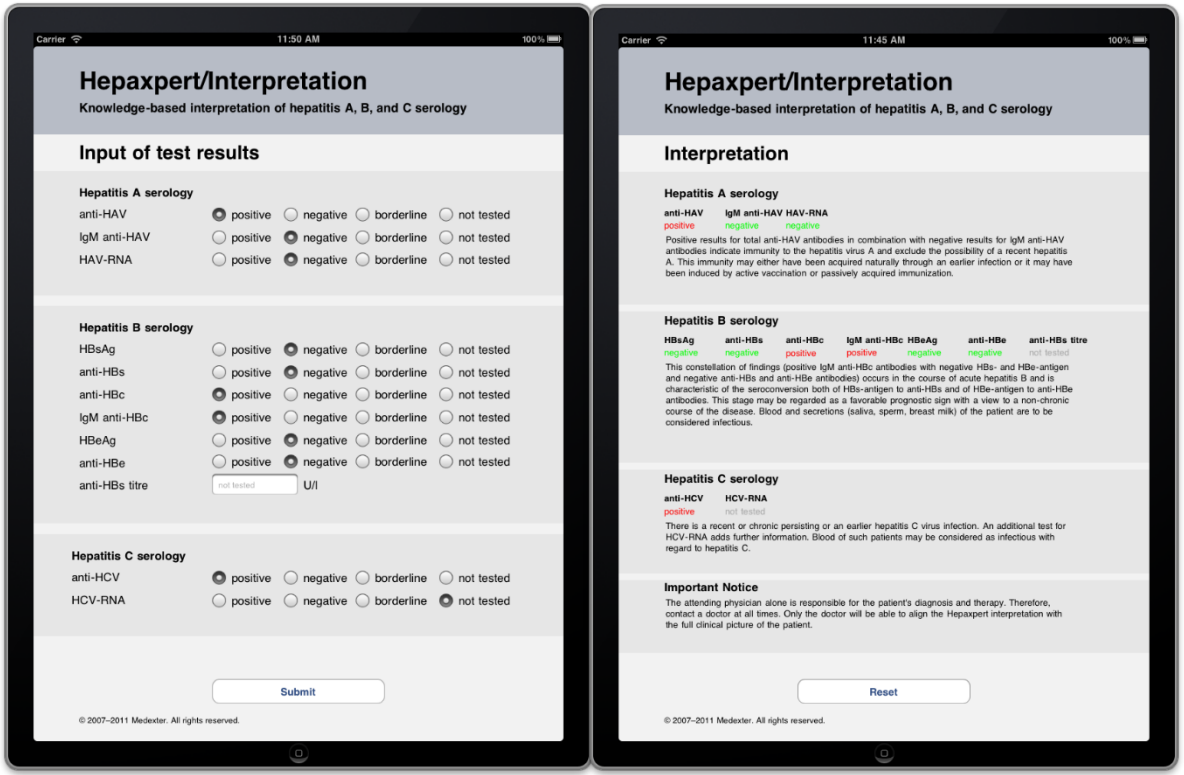
Hepaxpert/Interpretation in Soarian

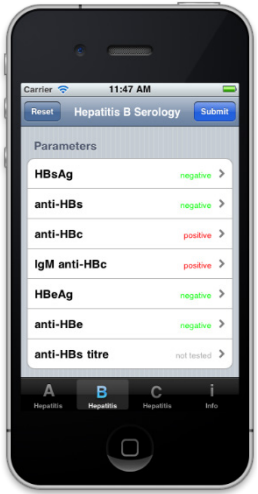


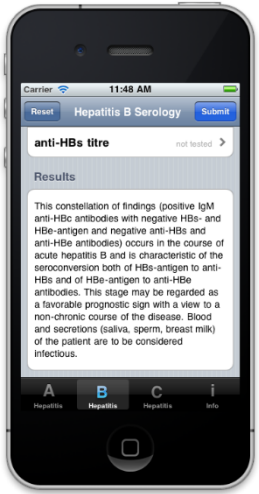
ORBIS Experter: Hepatitis serology diagnostics



Interpretation of hepatitis serology test results







Arden-Syntax-Server and MLMs at Universitätsklinikum Erlangen

Dr. Ixchel Castellanos

Interdisziplinäre Operative Intensivmedizin, Anästhesiologische Klinik

and

Dipl.-Inform. Stefan Kraus

Lehrstuhl für Medizinische Informatik

Tool zur Ausführung von Arden Syntax MLMs - Benutzer: kraussn_anonym - Orgeinheit: AN

BMI	Kalium	Natrium	Calcium	pH	Thrombopenie
Schockindex	Leukozyten	MMI Interaktionen	Anionenlücke	GFR	Tidalvolumen
Murrayscore	MELD-Score	PCT Allgemein	PCT Herz		
Diagnosen	MiBi Kneg	MiBi DRG	MiBi 7 Tage	Demo	

Patient: ****** ****** | ISH-Aufnahmenummer: ****** | Bettnummer: Bett 17 (5/1) | Orgeinheit: AN

MLM: ICM_BMI

Patient ****** ****** hat einen **BMI von 30.1**.

Patient hat **Adipositas Grad I (E66.00).**

HINWEIS: Diagnose E66.00 wurde noch nicht codiert!

Beenden Drucken

Tool zur Ausführung von Arden Syntax MLMs - Benutzer: kraussn_anonym - Orgeinheit: AN

BMI	Kalium	Natrium	Calcium	pH	Thrombopenie
Schockindex	Leukozyten	MMI Interaktionen	Anionenlücke	GFR	Tidalvolumen
Murrayscore	MELD-Score	PCT Allgemein	PCT Herz		
Diagnosen	MiBi Kneg	MiBi DRG	MiBi 7 Tage	Demo	

Patient: ****** ****** | ISH-Aufnahmenummer: ****** | Bettnummer: Bett 10 (4/2) | Orgeinheit: AN

MLM: ICM_ANIONENLUECKE

Die Anionenlücke von ****** ****** beträgt **4** mmol/l.

Berechnungsgrundlage

Letzter Natriumwert: 153 (Alter: 3 Stunden 31 Minuten)
Letzter Chloridwert: 127 (Alter: 3 Stunden 31 Minuten)
Letzter HCO3-Wert: 22 (Alter: 3 Stunden 31 Minuten)

Verwendete Formel: Anionenlücke = Natrium - Chlorid - HCO3

Anionenlücke sollte bei verwendeter Formel zwischen 8 und 16 liegen.

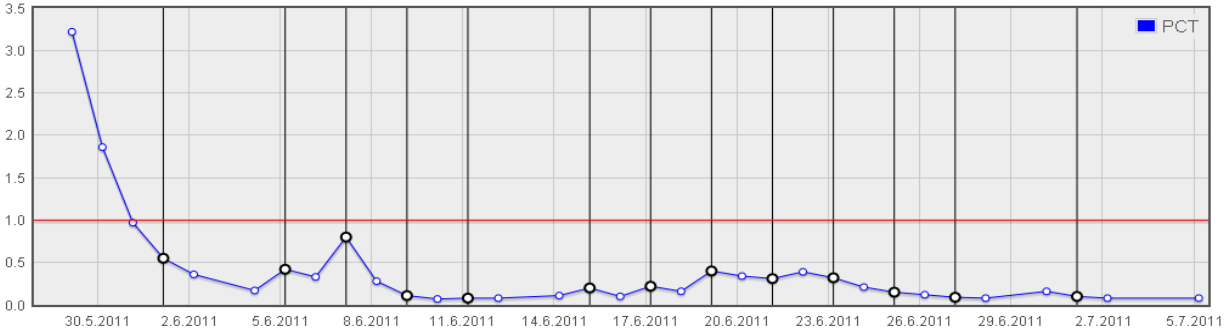
Beenden Drucken

Antwort von Medexter-Engine

Aktuell ist keine Procalcitoninmessung erforderlich.

Patient hat 33 Procalcitoninwerte.
Die letzte Procalcitoninmessung erfolgte am 05.07.2011 um 06:00 Uhr und ergab den Wert 0.08.
Die letzte Procalcitoninmessung liegt also 7 hours 28 minutes 34. seconds zurück.

Es wurden 13 vermeidbare Messungen gefunden: (4, 7, 9, 11, 13, 16, 18, 20, 22, 24, 26, 28, 31)
Das Einsparpotential liegt bei 182 Euro



Regression über alle Werte: -0.03
Regression über die letzten beiden Werte: 0
Trend: Veränderung pro Stunde: 0

#	Wert	Zeitstempel
1.	3.22	29.05.2011 um 06:00 Uhr
2.	1.86	30.05.2011 um 06:00 Uhr
3.	0.97	31.05.2011 um 06:00 Uhr
4.	0.55	01.06.2011 um 06:00 Uhr
5.	0.36	02.06.2011 um 06:00 Uhr
6.	0.17	04.06.2011 um 06:00 Uhr
7.	0.42	05.06.2011 um 06:00 Uhr
8.	0.33	06.06.2011 um 06:00 Uhr

Use Case: Hypoglycemia

- Hypoglycemia may seriously harm
- If patient is unconscious, it is difficult to notice
- The PDMS should actively notify the physician:

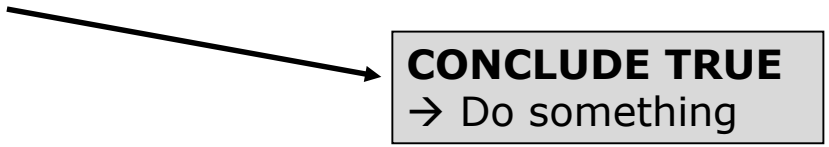
If glucose is less than 50mg/dl,

then send an SMS message to the physician.

by Stefan Kraus

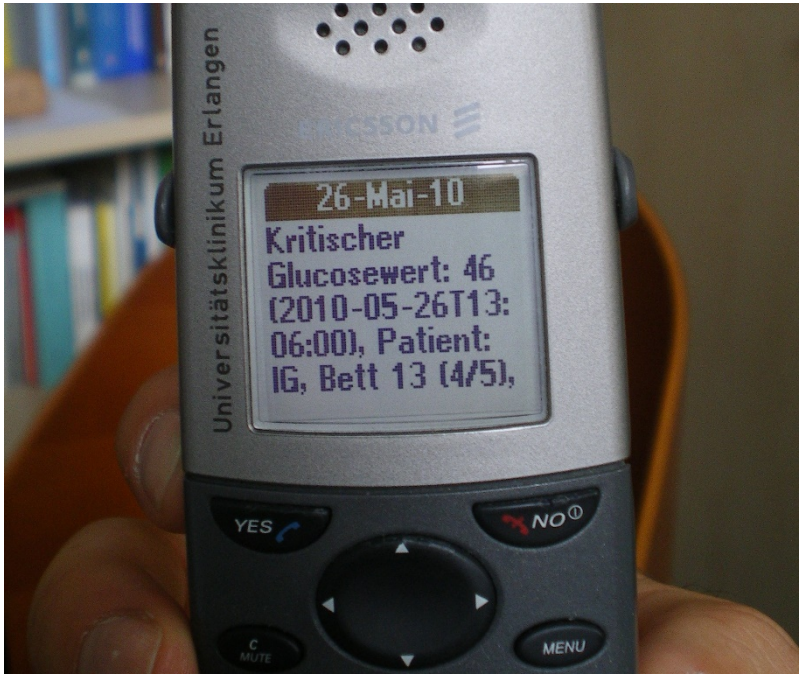
Use Case: Hypoglycemia

```
DATA:
LET glucose BE READ {…glucose…};
LET physician_DECT BE DESTINATION {sms:26789};

LOGIC:
IF LATEST glucose IS LESS THAN 50 THEN
  CONCLUDE true;
ENDIF;

ACTION:
WRITE „Warning…“ AT physician_DECT;
```



by Stefan Kraus

Use Case: Hypoglycemia



Event monitors are

„tireless observers, constantly monitoring clinical events“

(George Hripscak)

by Stefan Kraus

Implementation

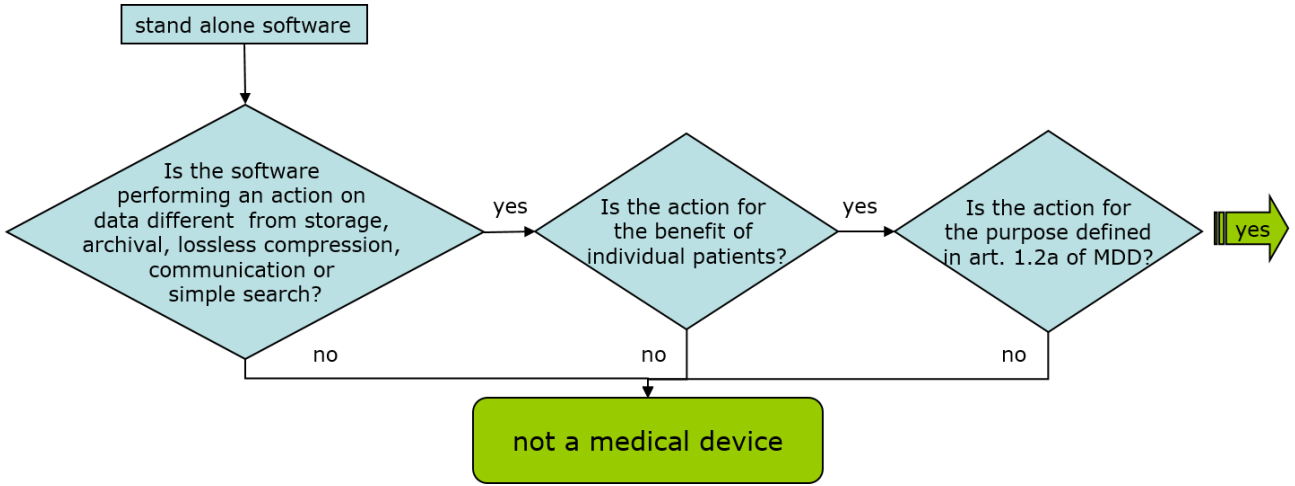
three-step approach

- awareness by clinicians, technicians, and administration; willingness to invest in evidence-based care, quality measures, legal confidence
- form a CDS governance committee (clinicians and technicians, backed by administration)
- demand and install specific CDS solutions and/or a general CDS tool for enterprise-wide knowledge authoring

Clinical perspectives

Regulatory affairs—I

- stand alone software
  - **Meddev 2.1/6:** Guidelines on the qualification and classification of stand alone software used in healthcare within the regulatory framework of medical devices (MDs) (January 2012)



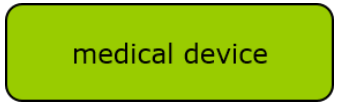
Regulatory affairs—II

- MDD 93/42/EEC
  - amended by Directive 2007/47/EG (21 September 2007)

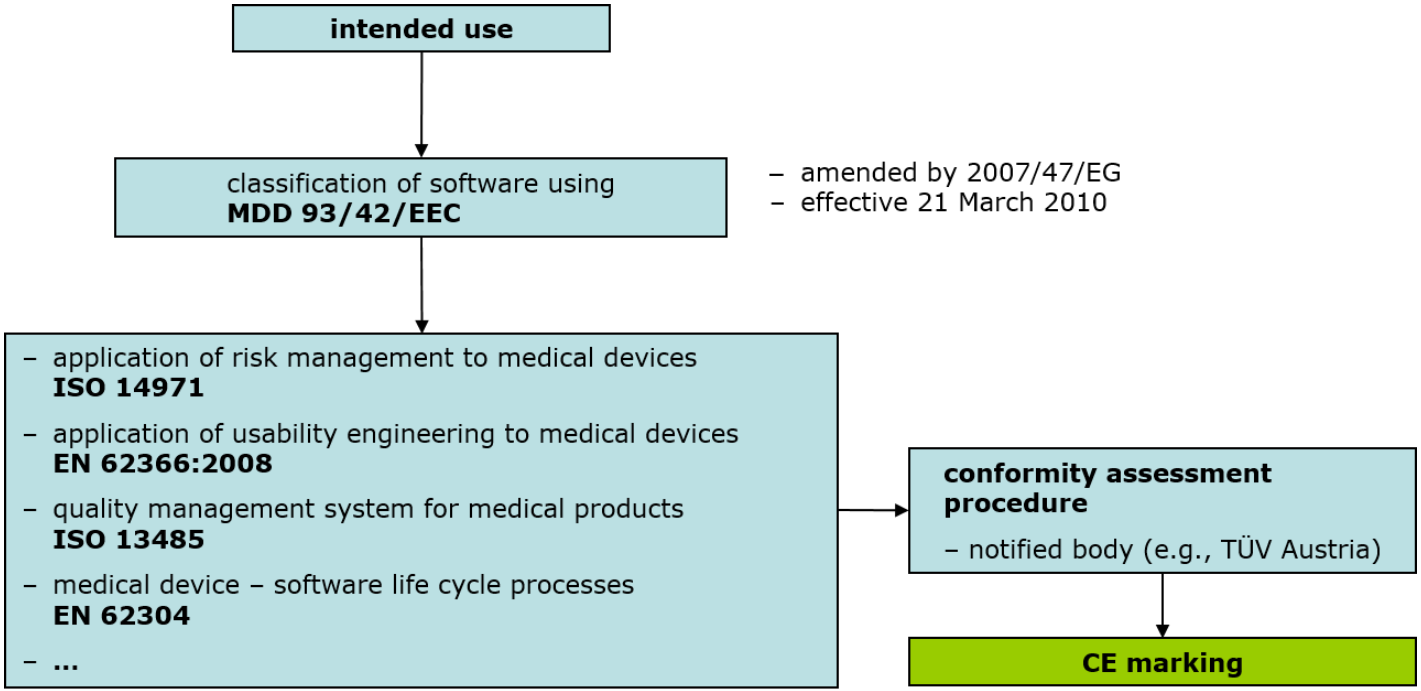
Article 1, Paragraph 2a (art. 1.2a of MDD):

Medical device (MD) means any instrument, apparatus, appliance, **software**, material or other article, whether used alone or in combination, … intended by the manufacturer to be used for human beings for the purpose of:

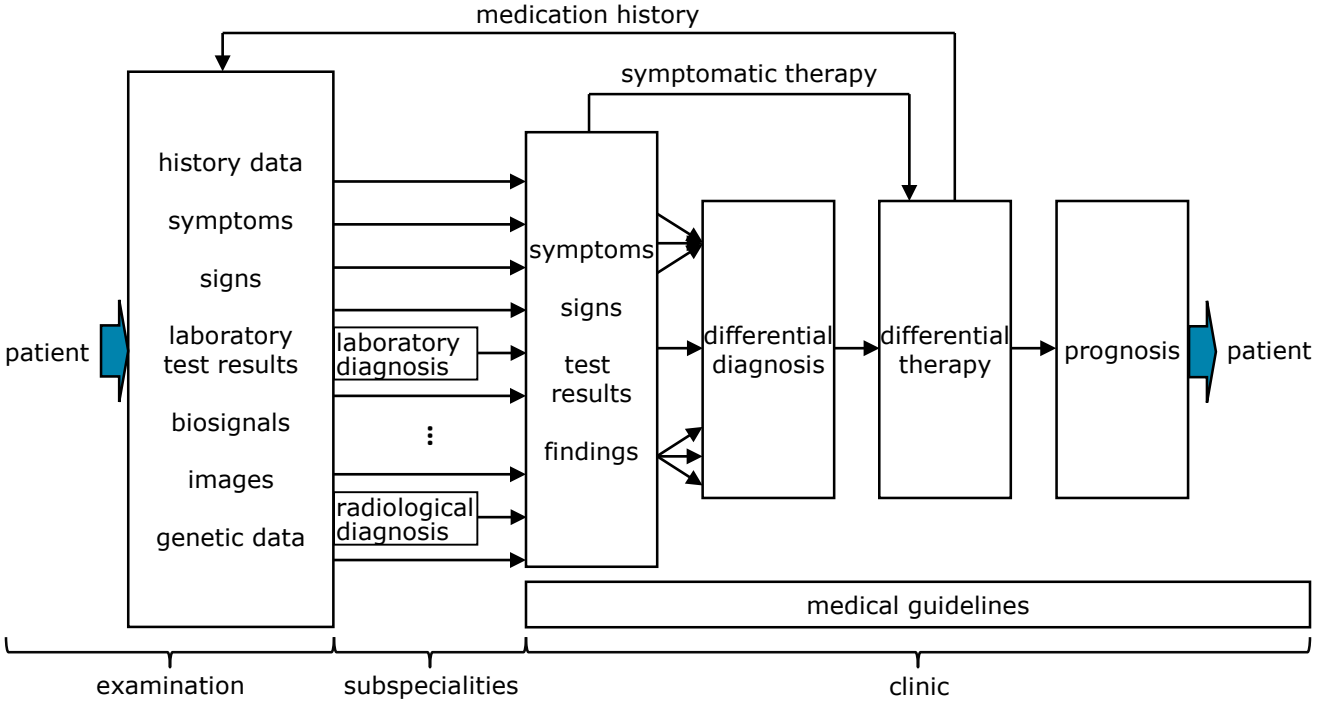
- diagnosis, prevention, monitoring, treatment, or alleviation of disease
- ...



Medical device certification



Clinical medicine



Clinical medicine: high complexity

- **sources of medical knowledge**
  - definitional
  - causal
  - statistical
  - heuristic

- **layers of medical knowledge**
  - observational and measurement level
  - interpretation, abstraction, aggregation, summation
  - pathophysiological states
  - diseases/diagnoses, therapies, prognoses, management decisions

- **imprecision, uncertainty, and incompleteness**
  - imprecision (=fuzziness) of medical concepts
    - due to the unsharpness of boundaries of linguistic concepts
  - uncertainty of medical conclusions
    - due to the uncertainty of the occurrence and co-occurrence of imprecise medical concepts
  - incompleteness of medical data and medical theory
    - due to only partially known data and partially known explanations for medical phenomena

- **"gigantic" amount of medical data and medical knowledge**
  - patient history, physical examination, laboratory test results, clinical findings
  - symptom-disease relationships, disease-therapy relationships, …
  - terminologies, ontologies: SNOMED CT, LOINC, UMLS, …

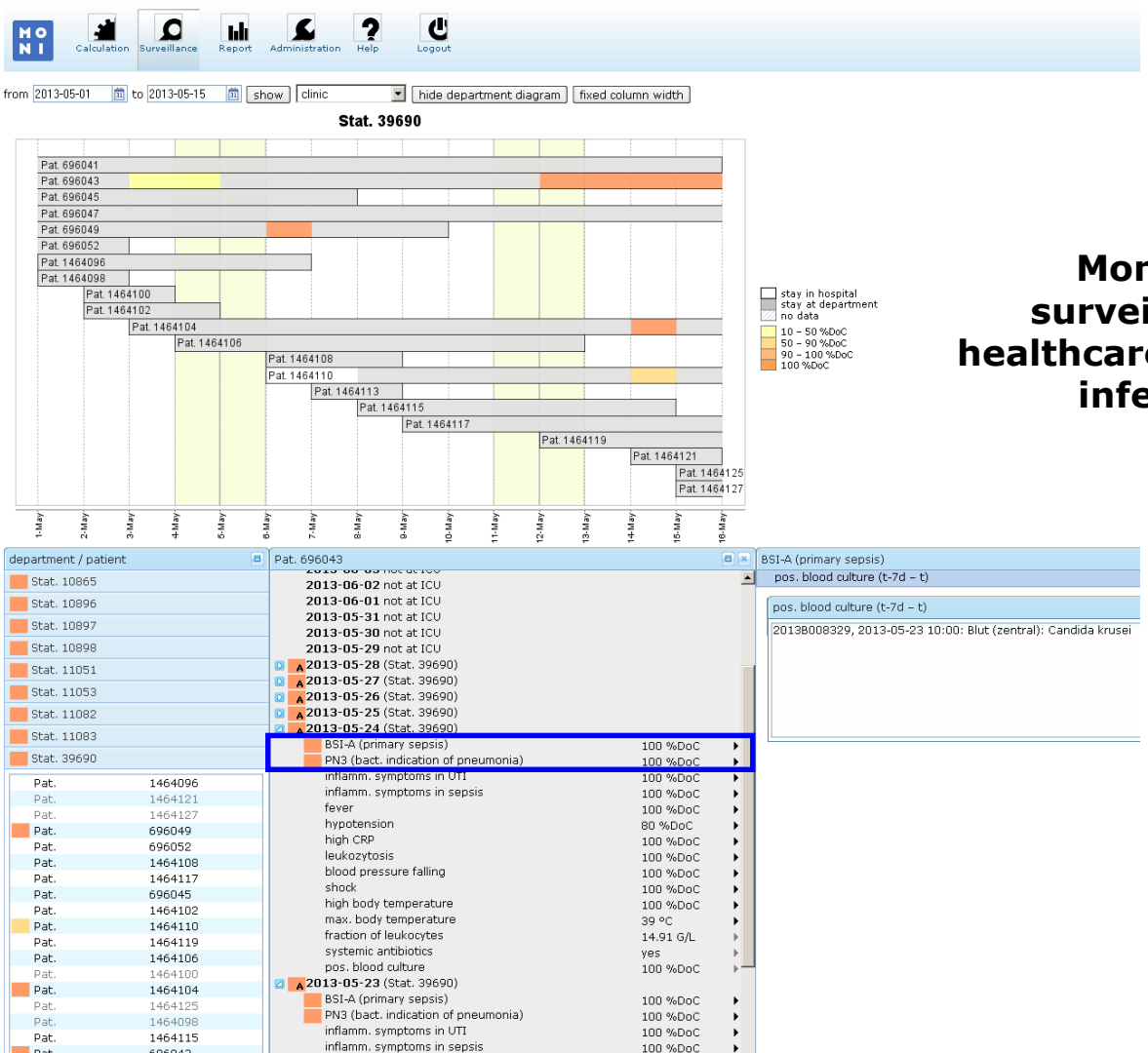
specialization, teamwork, quality management, computer support

Clinical medicine: hidden treasures

- holistic diagnosis
  - knowledge and intuition, symptomatic vs. causal therapy, medication history
  - patient‘s non-formalizable/non-digitizable data

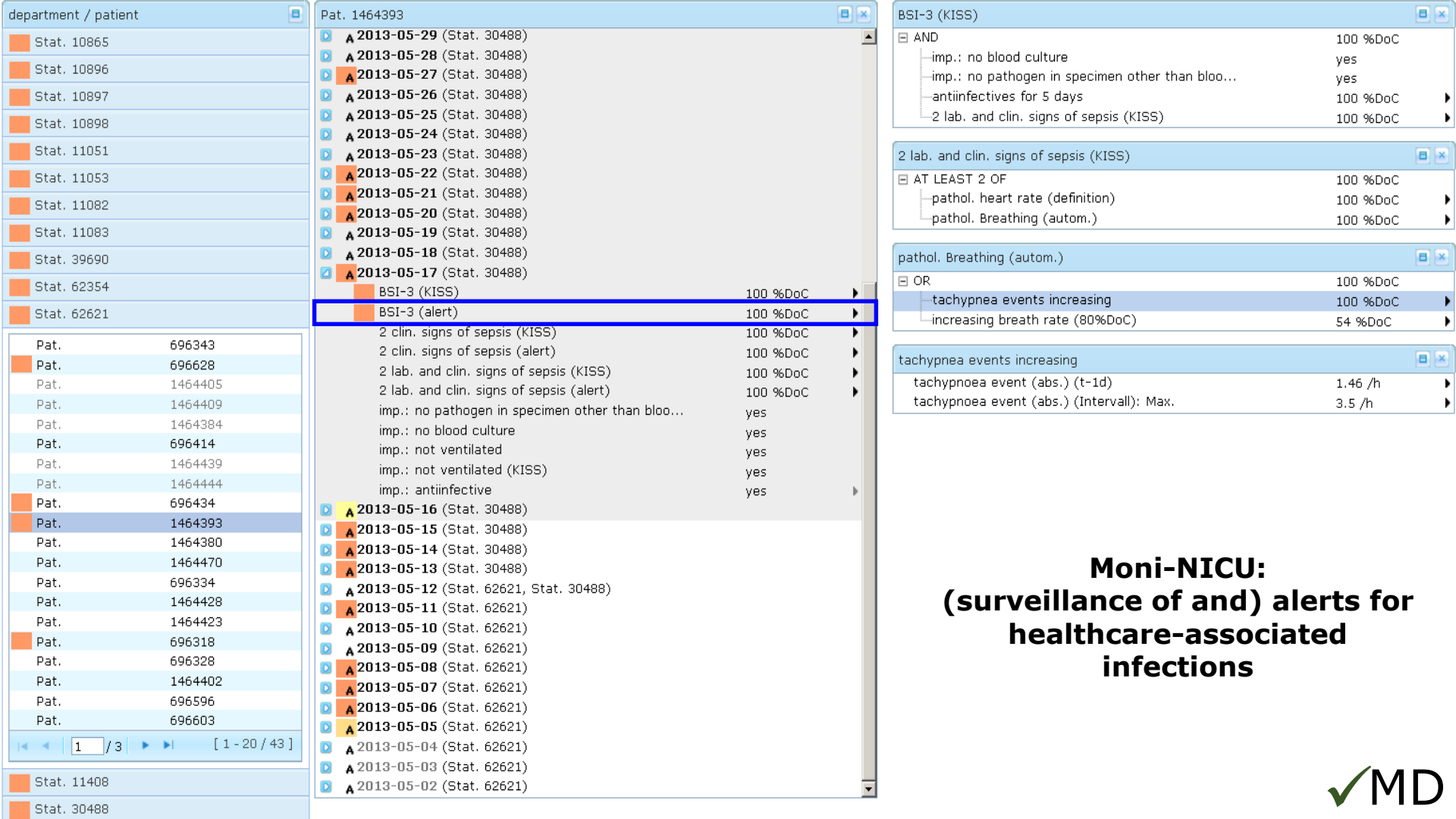
- probable vs. possible diagnoses
  - interpretation of findings, suspected diagnosis, clinical diagnosis, pathological diagnosis
  - pattern matching, most probable diagnosis, sensitivity, specificity, prevalence

- terminology in context
  - not every diagnostic term is a diagnosis
  - psychology: cold, flu, malaria, …

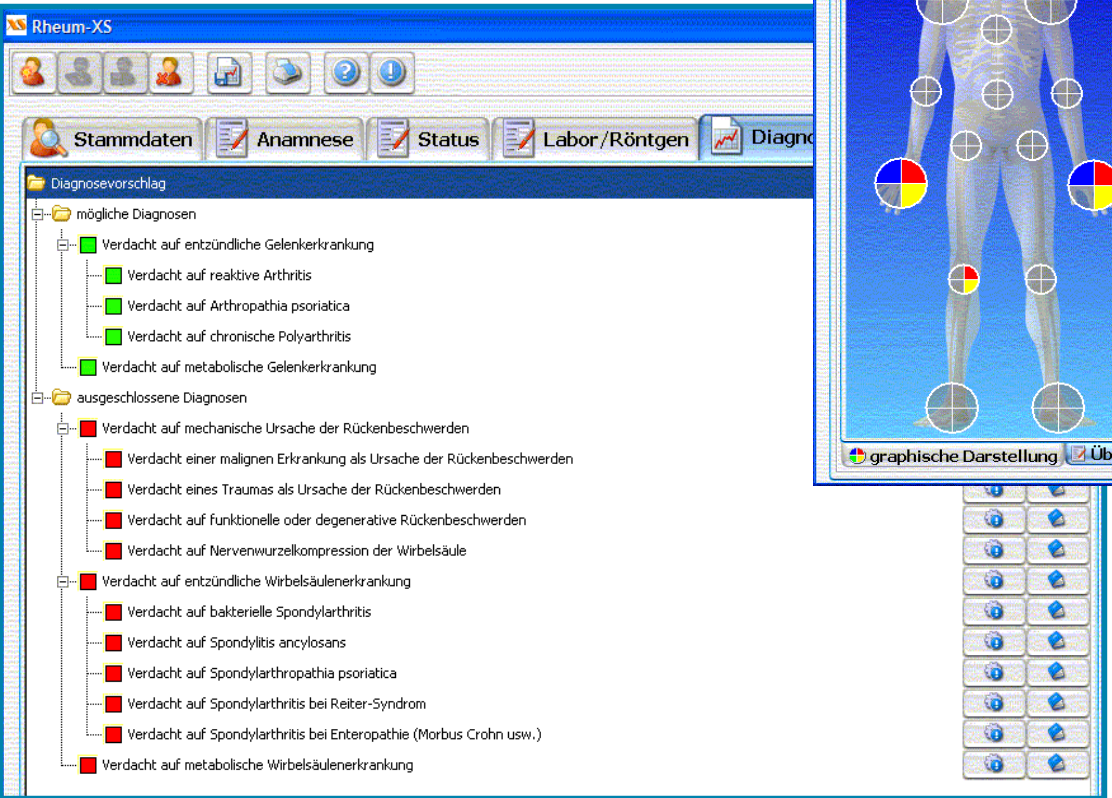


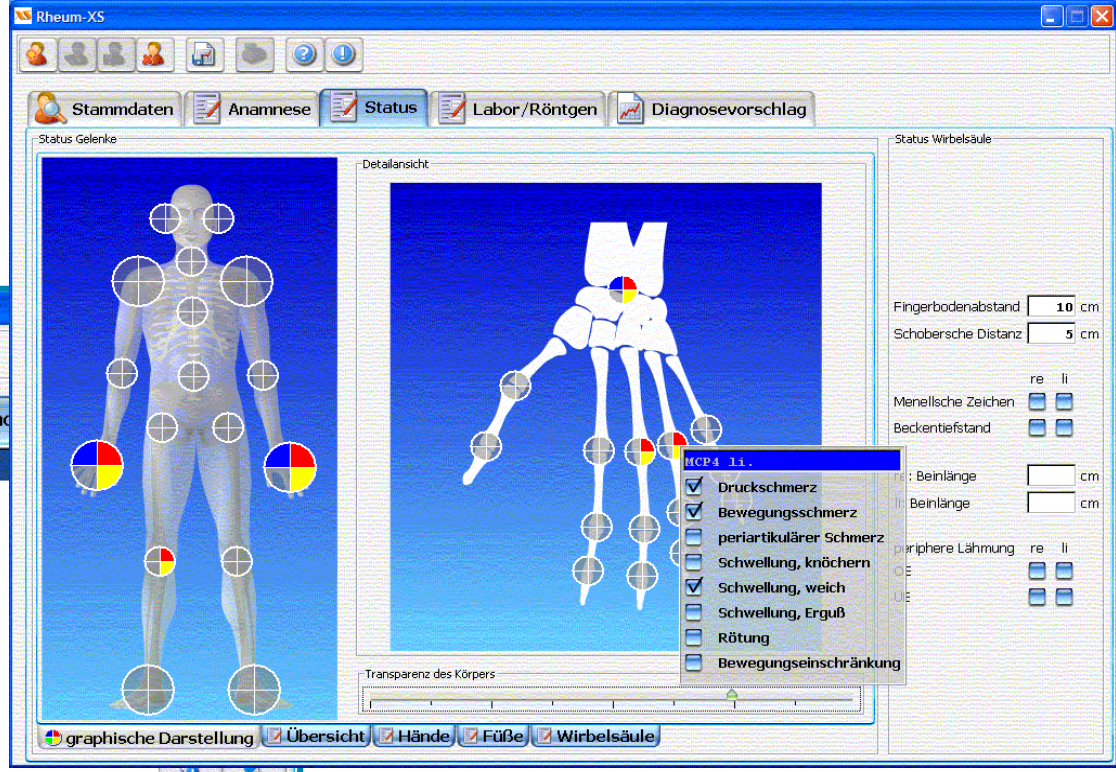
Moni-ICU: surveillance of healthcare-associated infections

xMD

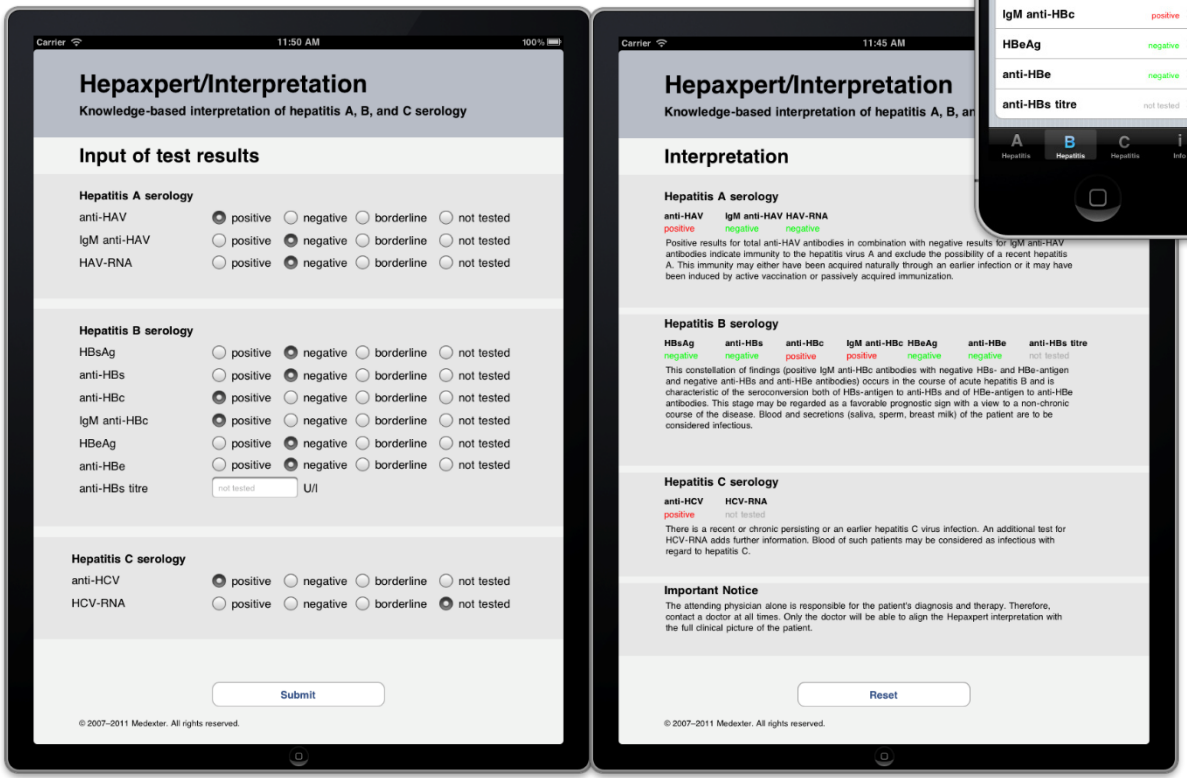

department / patient
Stat. 10865
Stat. 10896
Stat. 10897
Stat. 10898
Stat. 11051
Stat. 11053
Stat. 11082
Stat. 11083
Stat. 39690
Stat. 62354
Stat. 62621
Pat. 696343
Pat. 696628
Pat. 1464405
Pat. 1464409
Pat. 1464384
Pat. 696414
Pat. 1464439
Pat. 1464444
Pat. 696434
Pat. 1464393
Pat. 1464380
Pat. 1464470
Pat. 696334
Pat. 1464428
Pat. 1464423
Pat. 696318
Pat. 696328
Pat. 1464402
Pat. 696596
Pat. 696603
1 / 3
[1 - 20 / 43]
Stat. 11408
Stat. 30488
Pat. 1464393
2013-05-29 (Stat. 30488)
2013-05-28 (Stat. 30488)
2013-05-27 (Stat. 30488)
2013-05-26 (Stat. 30488)
2013-05-25 (Stat. 30488)
2013-05-24 (Stat. 30488)
2013-05-23 (Stat. 30488)
2013-05-22 (Stat. 30488)
2013-05-21 (Stat. 30488)
2013-05-20 (Stat. 30488)
2013-05-19 (Stat. 30488)
2013-05-18 (Stat. 30488)
2013-05-17 (Stat. 30488)
BSI-3 (KISS) 100 %DoC
BSI-3 (alert) 100 %DoC
2 clin. signs of sepsis (KISS) 100 %DoC
2 clin. signs of sepsis (alert) 100 %DoC
2 lab. and clin. signs of sepsis (KISS) 100 %DoC
2 lab. and clin. signs of sepsis (alert) 100 %DoC
imp.: no pathogen in specimen other than bloo... yes
imp.: no blood culture yes
imp.: not ventilated yes
imp.: not ventilated (KISS) yes
imp.: antiinfective yes
2013-05-16 (Stat. 30488)
2013-05-15 (Stat. 30488)
2013-05-14 (Stat. 30488)
2013-05-13 (Stat. 30488)
2013-05-12 (Stat. 62621, Stat. 30488)
2013-05-11 (Stat. 62621)
2013-05-10 (Stat. 62621)
2013-05-09 (Stat. 62621)
2013-05-08 (Stat. 62621)
2013-05-07 (Stat. 62621)
2013-05-06 (Stat. 62621)
2013-05-05 (Stat. 62621)
2013-05-04 (Stat. 62621)
2013-05-03 (Stat. 62621)
2013-05-02 (Stat. 62621)
BSI-3 (KISS)
AND 100 %DoC
imp.: no blood culture yes
imp.: no pathogen in specimen other than bloo... yes
antiinfectives for 5 days 100 %DoC
2 lab. and clin. signs of sepsis (KISS) 100 %DoC
2 lab. and clin. signs of sepsis (KISS)
AT LEAST 2 OF 100 %DoC
pathol. heart rate (definition) 100 %DoC
pathol. Breathing (autom.) 100 %DoC
pathol. Breathing (autom.)
OR 100 %DoC
tachypnea events increasing 100 %DoC
increasing breath rate (80%DoC) 54 %DoC
tachypnea events increasing
tachypnoea event (abs.) (t-1d) 1.46 /h
tachypnoea event (abs.) (Intervall): Max. 3.5 /h
Moni-NICU:
(surveillance of and) alerts for
healthcare-associated
infections
✓MD

Differential diagnosis of rheumatic diseases



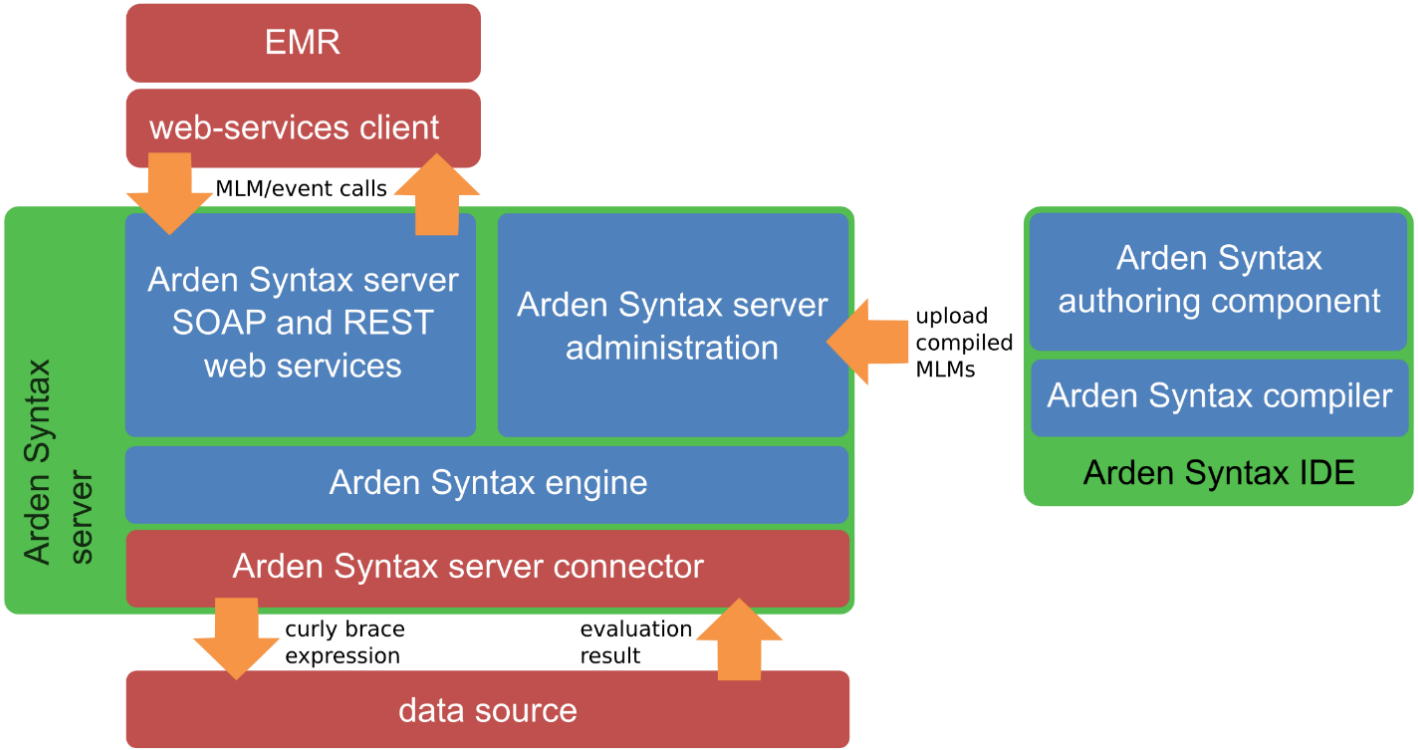


Clinically-oriented interpretation of hepatitis serology test results

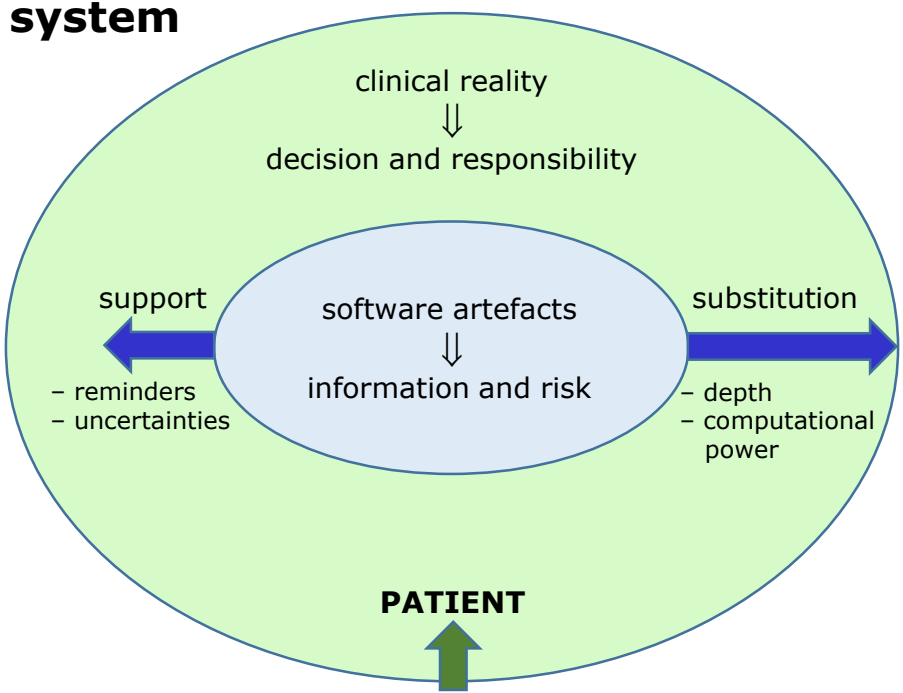


✓MD

Arden Syntax software: generic technology platform for clinical decision support



Clinical reality and software artefacts: a sociotechnical, interdependent system



certification of both clinicians and software ⇒ best care through best quality