Clinically Driven Logical Information Modeling and Data Exchange in Singapore

Colleen Brooks

IHIC 2011 (13-14 May 2011)
"What does it mean when we say our population will be older? It means there will be more demand on healthcare because older people are sick more often.

**But this also means it is a different pattern of healthcare**

So we have to respond to this by putting in more resources into our hospital system, building new hospitals.

… get the whole system to be structured properly so that it will be adapted to cater to the ageing population. To structure it properly means we need step-down care."

"And one key thing we must do with this step-down care is to link up our acute hospitals [...] with community hospitals, so that you can have the best of both worlds."

Prime Minister Lee Hsien Loong
National Day Rally 2009
Strategic vision of patients moving seamlessly across the healthcare system, receiving coordinated patient-centric care at the most appropriate settings.

Enabled by the National Electronic Health Record (EHR)
NEHR – Conceptual Long Term Vision

[Diagram showing the layout of patient records and associated data fields such as Name, Date of Birth, Primary Care Provider, Care Coordinator, Immunisations, Investigations, Procedures, Medications, and diagnoses.]
Need to Unleash The Benefits of Healthcare IT

Key infrastructure and technology needed

Network Infrastructure
- High Speed Network

Leadership and Governance

Interoperability and Standards
- Enterprise Architecture
- National Data Standards

Change Management

Strengthening Analytics
- Exploit the power of technology
Singapore’s National Data Standards

Establishing a suite of Standards that are:

- Clinically-Driven
- Easy to Use
- Internationally Recognised

To ensure clinical data included in the EHR can be:

- Shared and exchanged safely and reliably
- Relied on for the monitoring and care of patients
- Used meaningfully for secondary purposes including the production of clinical knowledge

Global Standards Engagements

- HL7 (Health Level Seven)
- IHTSDO (International Health Terminology Standards Development Organization)
- ISO TC215 on Health Informatics

Standards also provide a platform for long term semantic interoperability and research informatics
Moving from one direction to two—Interoperability Levels

- **Level 0**: no interoperability at all
- **Level 1**: technical and syntactical interoperability (no semantic interoperability)
- **Level 2**: two orthogonal levels of partial semantic interoperability
  - **Level 2a**: unidirectional semantic interoperability
  - **Level 2b**: bidirectional semantic interoperability of meaningful fragments
- **Level 3**: full semantic interoperability, sharable context, seamless cooperability

**Semantic interoperability**

- the ability to send human readable and computable records from place to place
- e.g. An electronic health record with vocabulary controlled, structured problem lists, medications, labs, and radiology studies sending this data into structured lists within a personal health record
- Semantic interoperability ensures that decision support software can interpret the transmitted data and perform quality and safety checks such as drug/drug or drug/allergy checking.
What may have been the problem?

Vocabulary
- Knowledge of words

Grammar
- Understanding of the structural rules that govern the composition of sentences, phrases, and words in any given natural language
- Semantics

Syntax
- Understanding of principles and rules of the language
- Sentence construction, etc

Transmission Errors
- e.g. typos, missing words, letters, etc
- Miscommunication

Translation
- Able to understand different language, grammar and Vocabulary

Knowledge
- Understand and analyse words from different languages
**Communication**

- **1-1 verbal communication**
  - Known target audience
  - Easy to agree on common understanding
  - Clarification
  - Many to Many?

- **Electronic communication**
  - Unknown audience
  - Common understanding?
  - Clarification?
  - Many to Many?
Interoperability Challenge in Singapore

- Lack of message standardisation in Singapore has hindered information sharing between clusters, healthcare sectors and facilities
  - Many variations in local HL7 v2 message profiles
  - Widespread use of locally defined Z-segments/fields
  - Lack of conformance quality testing
  - Disconnected terminology sets, which differ in their degree of pre-coordination due to differing local interfaces and structures
- To achieve interoperability in both directions, each new message variation must be both produced and consumed by each system
- Each system may need to support dozens of interfaces.
- NEHR requires uni and bi-directional semantic interoperability
- Need to support a hybrid SOA and MLLP environment for transporting messages
Standards follow the flow of information.
Different information models – Diagnosis

e.g., “Severe osteoarthritis of the left knee”

Data Source 1

Data Source 2

Data Source 3

All need to look the same in the NEHR.
What is the problem? – How are we tackling it?

**Vocabulary**
- Knowledge of words

**Grammar**
- Understanding of the structural rules that govern the composition of sentences, phrases, and words in any given natural language
- Semantics

**Syntax**
- Understanding of principles and rules of the language
- Sentence construction, etc

**Transmission Errors**
- e.g. typos, missing words, letters, etc
- Miscommunication

**Translation**
- Able to understand different language, grammar and Vocabulary

**Knowledge**
- Understand and analysis words from different languages

**SNOMED CT, LOINC, SDD (Singapore Drug Dictionary)**
- Use of International Standards
- Terminology Code sets

**MOHH Data Dictionary**
- Vocabulary Code Sets
- Includes SGDRM

**MCS (Mapping Code Sets)**
- Mapping Code Sets
- Migration Path

**NDDS (National Data Definition Specifications)**
- Structured data
- Syntax, Grammar and Vocabulary

**NXDS (Standard Exchange Formats)**
- HL7 (Health Level Seven), XML,
- Syntax and transmission error

**LIM (Logical Information Model)**
- Vocabulary
- Grammar
- Syntax
- Transmission
- Translation
- Knowledge
Standards Products

1. Terminology and Vocabularies
   - EXAMPLE - SNOMED CT,
   - Other LOINC, SDD (Singapore Drug Dictionary), MOHH Data Dictionary

2. MCS (Mapping Code Sets)
   - NEHR (local codes to Standards)
   - ICD Migration

3. NDDS (National Data Definition Specifications)

4. NXDS (Standard Exchange Formats)
   - HL7 (Health Level Seven) V2
   - LXXML

5. LIM (Logical Information Model)
Use Cases for Standards

- Messaging – exchanging transactional data
- Document Exchange
- Persistence – storing data in clinical systems
- Interoperability – semantics to enable bi-directional interoperability
- Querying – over NEHR + heterogeneous clinical systems
- Decision Support – national decision support rules over terminology and ‘LIM’
Data Improvement – Data ReUse

Terminologies and Vocabulary
NDDS and Exchange formats

General Practitioner
Acute-Care Hospital
Community Hospital

Dental
Message Mode
Registries
NEHR

LIM
Logical Information Model
SDA Information Model
SDA Data Model
SDA Data Mart

Maps
Standards Development Considerations

- **Clinical validation**
  - Need models that clinicians can understand and validate

- **Automated Processes**
  - Directly generate standards from clinician-validated models
  - Reduce risk of manual/programmer error (and dev. costs, below)

- **Data Quality**
  - Consistent and complete automated conformance checking
  - Improve reliability, consistency of data sent/received
  - Minimise data transformations required

- **Ease of Implementation** – by vendors
  - Generic models require higher level of training.
  - Use-case specific models are easier to implement

- **Minimise Costs**
  - Reduce standards development costs
  - Minimise maintenance costs arising from changing business requirements and evolving modelling advancements
  - Minimise long term costs of systems and interfaces
<table>
<thead>
<tr>
<th>Feature</th>
<th>HL7 v2</th>
<th>HL7 v3</th>
<th>CEN 13606</th>
<th>openEHR</th>
<th>CDA/CCD</th>
<th>XML/Web Service</th>
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<tr>
<td>Coverage (i.e. to realise full EHR)</td>
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<td>++</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>-</td>
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<tr>
<td>Expressive power for clinical data</td>
<td>+</td>
<td>+++</td>
<td>++ (weaker RM)</td>
<td>+++</td>
<td>+++ as per v3</td>
<td>-</td>
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<td>++ (there are problems with it)</td>
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<td>+</td>
<td>+ (XPath)</td>
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<td>++</td>
<td>++</td>
<td>++ this is what NHS are doing</td>
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<td>++</td>
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<td>+++</td>
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<td>++</td>
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<td>++ (it is a messaging spec)</td>
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<td>- (neither v2 nor v3 are persistence specs)</td>
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<tr>
<td>Terminology/Ontology bindings</td>
<td>++</td>
<td>+++ (v3 has richer structured datatypes that better support post-coordination)</td>
<td>+++</td>
<td>+++</td>
<td>+++ (as per v3 esp CD datatype)</td>
<td>+++ (using RDF and OWL)</td>
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An **implementation-independent information model** for healthcare data exchange

Developed using an **evidence-based approach**, involving the analysis of **several million existing messages**, relevant message profiles and local implementation groups and **Clinician-driven approach** to gathering **new requirements**

Built upon a standards-based **Logical Reference Model (LRM)**.

Includes a set of reusable **clinical building blocks** (‘archetypes’), which can be further constrained and then assembled into ‘templates’ to meet specific use cases.

Defines the **structure, constraints and reference terminology** binding for clinical concepts used within healthcare messages.

Expressed using a **machine-readable format**, used to automatically generate exchange format specifications, conformance validation software, user interfaces, human readable documentation.

Allows clinical systems to populate messages using their native interface terms, **resolving pre-coordination differences with the help of specialised ‘design pattern’ constructs.**
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<th>ADT</th>
<th>Lab</th>
<th>Radiology</th>
<th>Pharm Order</th>
<th>Pharm Dispense</th>
<th>ACIDS Phase 1</th>
<th>ACIDS Goal State</th>
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<td>✓</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Logical XML (LXML) / ‘Green-13606’
- Automated, serialisation of a Template
- Has simple, generic XSLT to convert to/from LRM
- Forms HL7 SOA Service Definitions
- Can be used to generate ‘Green-CDA’ or ‘CDA-r1’

HL7 v2.3.1 messages
- Required by some systems in Singapore
- Extended with LIM-semantics using ‘Structured-OBX-segments’
- Uses some HL7 v2.6 data types (e.g. some CE fields have been upgraded to CNE/CWE to support Singapore’s terminology requirements).
Sample Logical XML (LXML) Snippet

**NDDS snippet**

<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
<th>Description</th>
<th>CLUSTER</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>E8.21.1</td>
<td>Investigation Name</td>
<td>part</td>
<td>ELEMENT.value: CO.CWE (Concept Descriptor - Coded or Text)</td>
<td>1</td>
</tr>
<tr>
<td>E8.21.2</td>
<td>Additional Description</td>
<td>part</td>
<td>ELEMENT.value: CO.CWE (Concept Descriptor - Coded or Text)</td>
<td>0..1</td>
</tr>
<tr>
<td>E8.21.4</td>
<td>Context</td>
<td>part</td>
<td>CLUSTER</td>
<td>0..1</td>
</tr>
<tr>
<td>E8.21.5</td>
<td>Procedure Site Direct</td>
<td>part</td>
<td>CLUSTER</td>
<td>0..Many</td>
</tr>
<tr>
<td>E8.21.6</td>
<td>Specimen</td>
<td>part</td>
<td>CLUSTER</td>
<td>0..1</td>
</tr>
<tr>
<td>E8.21.7</td>
<td>Priority</td>
<td>part</td>
<td>ELEMENT.value: CO.CWE (Concept Descriptor - Coded or Text)</td>
<td>0..1</td>
</tr>
<tr>
<td>E8.21.8</td>
<td>PUNCT Indicator</td>
<td>part</td>
<td>ELEMENT.value: CO.CWE (Concept Descriptor - Coded)</td>
<td>0..1</td>
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<tr>
<td>E8.21.9</td>
<td>Category</td>
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<td>Type</td>
<td>part</td>
<td>ELEMENT.value: CO.CWE (Concept Descriptor - Coded)</td>
<td>0..1</td>
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</table>

**LXML XSD**

```xml
<xsd:complexType name="investigation_item">
  <xsd:complexContent mixed="true">
    <xsd:extension base="SG_CLUSTER">
      <xsd:sequence>
        <xsd:element name="investigation_name" type="CD_ELEMENT" minOccurs="0" />
        <xsd:element name="additional_description" type="CO.CWE" minOccurs="0" />
        <xsd:element name="context" minOccurs="0" />
        <xsd:element name="procedure_site_direct_lateralig" minOccurs="0" />
        <xsd:element name="priority" type="CD_ELEMENT" minOccurs="0" />
        <xsd:element name="punct_indicator" type="CD_ELEMENT" minOccurs="0" />
        <xsd:element name="category" type="CD_ELEMENT" />
        <xsd:element name="type" type="CD_ELEMENT" minOccurs="0" />
        <xsd:element name="clinical_notes" type="ST_ELEMENT" minOccurs="0" />
      </xsd:sequence>
    </xsd:extension>
  </xsd:complexContent>
</xsd:complexType>
```

**NXDS LXML Instance**

```xml
<investigation_item component_type="CLUSTER">
  <investigation_name component_type="ELEMENT">
    | <value codeSystem="2.16.840.1.1133883.6.96' code="15264007" />
    | <displayName value="Lipid Panel" />
  </value>
</investigation_name>
<category component_type="ELEMENT">
  | <value codeSystem="MOH-DD" code="Laboratory" />
</category>
<type component_type="ELEMENT">
  | <value codeSystem="2.16.840.1.1133883.6.96' code="15220000" />
  | <displayName value="laboratory test" />
</value>
</type>
</investigation_item>
```
Conclusion

- Clinician-driven and validated logical modelling drives all information standards
- Artifacts can be automatically generated from clinician-validated models (reduces clinical risk)
- Enables normalization of structure and terminology semantics (design patterns) for safer interoperable querying
- Supports hybrid transport protocol environment (e.g. SOA, MLLP)
- Establishment of LIM is a critical step in achieving clinically-driven bi-directional semantic interoperability in Singapore

**Ultimate goal:** Greater clinical safety in the interchange of healthcare information
Thank you