Building a portable data and information interoperability infrastructure — framework for a standard Taiwan Electronic Medical Record Template

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1. Background

- The data sources of a tradition EHR are from various hospital information systems.
- They are not stored independently without the support of hospital information systems until the incarnation of XML technology.
- The sharing of data among healthcare organizations not only imposes functional demands of the exchange but requires semantic communication as well.
- Usually, people develop standards and technology to achieve the above interoperability of data sharing.
- There are currently many standard development organizations (SDOs), such as HL7 and IHE, which are dedicated to developing their own standards for the above objectives.
- However, in order for this effort to succeed, the development of a standard must take into account not only the means of achieving the stated objectives but also external factors such as the acceptance of the associated technology in order to reduce resistance to standardization.
2. Interoperability of data exchange

- EHRs are a part of a very complicated information system framework that involves many related standards, which are supposed to provide interoperability within healthcare systems (HL7 CDA, openEHR, and ASTM-CCR...)
- The definition of interoperability From the IEEE:
  The ability of two or more systems or components to exchange information and to use the information that has been exchanged.
For EHR data sharing, interoperability can be divided into two dimensions.

Aguilar defined interoperability as follows:

1. **Functional and syntactic interoperability** is the ability of two or more systems to exchange information through functionality and defined message structures so that this information is readable by humans on the receiving end.

2. **Semantic interoperability** is the ability for information shared by systems to be understood at the level of formally defined domain concepts, so that the information can be processed by computers on the receiving end.

3. Why TMT?

- CDA is an exchange specification, not an authoring specification.
- Since the CDA is not deterministic for document creation, a set of EHR templates is required for local standardized clinical documents.
- Current research around the world has indicated that implementation of an EHR sharing standard needs to take into account other relevant standards and be localized in order to meet actual requirements.
  - Ex) Japan's MR, Image, Text-Information Exchange (MERIT-IX or MERIT-9)
    - a set of patient information exchange guidelines using MML
    - HL7 and ASTM CCR for Continuity of Care Documents (CCDs)
    - Germany's Standardization of Communication between Information Systems in Physician Offices and Hospitals using XML (SCIPHOX).
- Taiwan needs a set of local standard EHR templates in order to achieve functional and semantic interoperability within the country.
- The TMT project is a milestone effort on the path to a fully interoperable and portable document-based EHR.
4. Requirements for developing the TMT

The TMT was established with the following requirements in mind:

4.1. **Transformable** to international medical information standards

4.2. Having a **minimal impact** on existing healthcare systems

4.3. **Easy** to implement and deploy

4.4. Compliant with **current laws and regulations**
4.1 Transformable to international medical information standards

The HL7 CDA 2.0. - The CDA is an exchange specification, not an authoring specification.

HL7 suggests the general approaches for EHR exchange:

General approaches: constrain or transform
• **constrain**: emit valid CDA directly from the authoring system using a schema that isn’t CDA
• **transform**: example - emit local XML, map to CDA
• For technical considerations, the team used the **transformation approach** for the TMT so that it will be transformable to CDA as seen in **Fig. 1**.

Fig. 1. The transform approach (from the HL7 web site)
4.2 Having a minimal impact on existing healthcare systems

- The TMT was designed to use forms as self-contained units, which are already commonly used by medical professionals.

- A request was sent to 598 hospitals nationwide, and 200 hospitals responded providing as many as 20,056 forms.

- The released draft proposal uses the common request for comments (RFC) approach to solicit comments from the public.

- 9 technical committees (TCs)
  - Physicians, Traditional Chinese medicine, Nursing, Medications, Dental, Examinations and lab tests, Technology assessments, Standard harmonization, and ethical, legal, and social issues

- A technical steering committee (TSC)
  - The TSC itself was comprised of about 30 experts
  - All the chairs and co-chairs of each TC, who had the responsibility of directing and approving work on all final documents.
4.2-1. The process of defining the TMT standard

(A) collecting and examining forms by medical specialists
(B) classifying the over 20,000 forms into 70 categories based on their similarities
(C) drafting TMT format proposals by the research team
(D) meeting with experts to form a consensus
(E) encoding the TMT schema with reusable components
(F) building a prototype system for managing the TMT forms
(G) releasing a schema for specific TMT forms

Fig. 2. Description of the process used for defining the TMT contents.
4.3. Easy to implement and deploy

**Evaluation project** to validate the practicability of the TMT standard

three different levels of healthcare organizations to participate in the prototyping of the TMT system:

1) a 650-bed medical center (Wanfang Hospital, Taipei)
2) a 200-bed local hospital (Kangning Hospital, Taipei)
3) a clinic (Shinhe Clinic, Taipei)

The preliminary results showed that in electronically sharing over 40,000 medical sheets in the TMT forms within 1 week, **no mapping errors occurred.**
4.4. Compliant with current laws and regulations

1) Legal professionals were invited to review all relevant laws which might pertain to the deployment of TMT in Taiwan, the *Medical Care Act, Physician Act, Computerized Personal Information Act, Electronic Signature Act, Personal Data Protection Ordinance, and Healthcare Organization EMR, Creation and Management Ordinance.*

2) They concluded that the TMT can be deployed in a way compliant with all existing Taiwanese laws and regulations.
5. The framework of the TMT

- The basic principle in the design of the TMT formats was to develop a set of templates for representing the EHR contents at a certain point in time.

The definitions for forms and sheets.

1. **TMT form**: Traditional paper forms are treated as TMT forms. Each TMT form is represented as a single XML schema. Each form has its own corresponding schema defining its structure and content.

2. **TMT sheet**: A sheet is an instance of a TMT form. Hence, a sheet is an XML file that contains data in a specific form.
The TMT standard is composed of multiple schemas representing different forms in a medical record.

Fig. 3. Forms and sheets in the TMT
6. The anatomy of a TMT form

- Each TMT form is composed of four major parts:

Fig. 4. Taiwan EMR Template form structure.
The header stores four different kinds of information

1) The document information: items such as document ID, submission ID (for document grouping), and set ID (for version control).

2) The basic patient information: patient ID, gender, age, emergency contact, etc.

3) The author information: the humans and/or machines that authored the document.

4) Healthcare organization information: is given on the healthcare organization which is in charge of maintaining the document.
6.2. Body

- The body of each form is where the main information is stored. Different forms have different layouts, but they all follow the basic section-component structure.

Fig. 5. The framework of TMT component section.
6.3. User-defined section

This allows users to fit their own contents into a customized layout. The main function is to accommodate special data-capture needs of each organization. However, producing customized layouts could result in a lower level of interoperability.

6.4. Signature

The TMT form uses the W3C XML signature standard. This allows the incorporation of digital signatures of healthcare organizations and personnel.
6.5. Sections and components

- **The section** is the main data structure in the body. 
  1) section information: section ID, code, title, author, etc,
  2) narrative block
  3) entry
  4) components

The narrative block carries the human-readable text, while the entries carry machine-readable data.

- **The components** represent references to other sections which can be reused and included in this specific section. The team has defined more than 40 reusable TMT sections such as a basic patient information section, past medical history section, allergy history section, family history section, etc.
7. An example of a TMT form

• TMT forms are modeled after traditional paper forms for medical records. So far, 70 TMT forms (schemas) have been completed, representing commonly used paper forms found in traditional medical records.

• An example of a prescription form representing the TMT schema is shown in Fig. 6. The schema of the prescription form is the simplest form of the TMT.
Fig. 6. An example showing the schema of the TMT prescription form.
### Taiwan EMR Template form classification

All 70 TMT forms are categorized into 6 major groups:

<table>
<thead>
<tr>
<th>1. Outpatient</th>
<th>3. Inpatient</th>
</tr>
</thead>
<tbody>
<tr>
<td>General outpatient encounter</td>
<td>Admission note</td>
</tr>
<tr>
<td>Medical outpatient encounter</td>
<td>Progress note</td>
</tr>
<tr>
<td>Surgical outpatient encounter</td>
<td>Inpatient medical order</td>
</tr>
<tr>
<td>Family medicine outpatient encounter</td>
<td>Consultation note</td>
</tr>
<tr>
<td>Gynecological outpatient encounter</td>
<td>Discharge summary ...</td>
</tr>
<tr>
<td>Pediatric outpatient encounter</td>
<td></td>
</tr>
<tr>
<td>Otolaryngology outpatient encounter</td>
<td></td>
</tr>
<tr>
<td>Dermatology outpatient encounter</td>
<td></td>
</tr>
<tr>
<td>Respiratory outpatient encounter</td>
<td></td>
</tr>
<tr>
<td>Orthopedics outpatient encounter</td>
<td></td>
</tr>
<tr>
<td>Optometry outpatient encounter</td>
<td></td>
</tr>
<tr>
<td>Anesthesiology outpatient encounter</td>
<td></td>
</tr>
<tr>
<td>Psychiatric outpatient encounter</td>
<td></td>
</tr>
<tr>
<td>Neurosurgery outpatient encounter</td>
<td></td>
</tr>
<tr>
<td>Neurology outpatient encounter</td>
<td></td>
</tr>
<tr>
<td>Gastroenterology outpatient note</td>
<td></td>
</tr>
<tr>
<td>Radiology outpatient encounter</td>
<td></td>
</tr>
<tr>
<td>Urology outpatient encounter</td>
<td></td>
</tr>
<tr>
<td>Dentistry encounter</td>
<td></td>
</tr>
<tr>
<td>Chinese medicine outpatient encounter</td>
<td></td>
</tr>
<tr>
<td>Prescription sheet ...</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. Nursing</th>
<th>5. Test report form</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Checkup application form</td>
</tr>
<tr>
<td></td>
<td>Laboratory testing application form</td>
</tr>
<tr>
<td></td>
<td>Checkup report</td>
</tr>
<tr>
<td></td>
<td>Laboratory test report ...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Emergency</th>
<th>6. Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency trauma surgery note</td>
<td>Patient health summary</td>
</tr>
<tr>
<td>Emergency triage form</td>
<td>Transfer sheet</td>
</tr>
<tr>
<td>Emergency assessment form</td>
<td>Anesthetization record</td>
</tr>
<tr>
<td></td>
<td>Nutrition consultation record</td>
</tr>
</tbody>
</table>
8. The concept of a submission set

- A submission set
  - refers to a collection of all medical records generated during a given consultation or visit to a specific healthcare organization.
  - Outpatient: an outpatient note, prescription, and lab test application form.
  - Inpatient: an admission note, progress notes, operation notes, nursing records, etc.

- The header of each sheet therefore includes a submission set ID along with the total number of sheets in that group of submission to ensure completeness of the data.

- Each submission set:
  - a unit for data encryption and/or a signature
  - This prevents the leaking of information from individual sheets leading to erroneous assumptions about the full contents of the EHR.
  - include multimedia attachments such as JPEG, AVI, GIF, and other binary file formats (Fig. 7).
Fig. 7. TMT submission set structure.
9. Comparison with other international EHR exchange standards from the user's perspective

Other EHR exchange standards currently being developed, the Taiwan EMR Template offers the following features.

- 9.1. Clearly defined data storage
- 9.2. Rapid technical implementation
- 9.3. Ease of learning
- 9.4. Future expandability
- 9.5. Level of localization
9.1. Clearly defined data storage

- The TMT uses a form-based representation in which each form from paper-based medical records has its own specific schema. This creates a system framework containing multiple schemas. Because the way data stored in each sheet is clearly defined, users can quickly locate any information.
9.2. Rapid technical implementation

- Because of the form-based representation, an EHR form can be developed which incrementally represents the entire EHR. They need thorough browser system prototyping, and revisions can be performed form-by-form. This therefore simplifies the new system design and deployment.
9.3. Ease of learning

- A single schema that represents the entire EHR not only increases structural complexity but also makes it difficult to learn. With the TMT's form-based approach, users can begin with simpler forms while familiarizing themselves with the standard. Our experience showed that a physician can learn to read and revise a TMT form with a 10–15-min introduction.
9.4. Future expandability

• The form-based design allows different forms in the medical record to be represented in independent schemas. If necessary, new schemas can be added in the future to expand the coverage of the variety of clinical documents.
9.5. Level of localization

• Since the TMT standard was designed to accommodate local needs, it satisfies the requirement for region-specific localization. Technical barriers also affect system implementation due to semantic interoperability among medical facilities.

• The TMT has very clear definitions of its exchange data contents. So, semantic interoperability can be achieved with the TMT.
The Taiwan EMR Template is a standard: aims to achieve functional & semantic interoperability in EHR exchanges.

Through XSLT technology, TMT XML files -transform-> the HL7 CDA format (which can facilitate international interoperability in the future)

In order to fit into the current environment,
(1) The TMT was designed using forms, a concept already familiar to medical professionals.
(2) For the project, we carried out system prototyping, training, and education and tried as much as was possible to ensure that the standard is easy to implement.
(3) We have reviewed all relevant laws which might affect EHR exchanges in Taiwan, and the TMT standard can be implemented in a way that complies with all current laws and regulations.

The project has achieved the requirements of:
(1) being transformable to international medical information standards
(2) having a minimal impact on existing healthcare systems
(3) being easy to implement and deploy
(4) being compliant with current laws and regulations.
10- 1.

- In 2007, the Department of Health (DOH) in Taiwan determined to allocate about US$1 million to promote the TMT format in ten medical centers which collectively provide more than 10 million outpatient visits a year.

- This project will also help refine the TMT into a national standard for EHR documentation and exchange in Taiwan.
• Because of the maturity of the XML technical standards, such as XSLT, XPath, XQuery, etc., it is easy to transform a required document into a variety of document formats, as shown in Fig. 8.

• The XML technology is currently the mainstream choice of data packaging for sharing information.

• It is also possible to use XSLT to convert among various medical information standards.

• It is this adoption rate that will ultimately determine whether the standard is retained or discarded.
Fig. 8. Taiwan EMR Template (TMT) document transformation.
The design of the TMT format provides the basis for developing a document-based information standard and information interoperability infrastructure for the healthcare system in Taiwan.

With the help of the TMT, the document-based EHR can also be used for digital signatures and encryption of files that can be delivered to individual patients for personal health management purposes.
Acknowledgments

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