

# Putting Health Record Interoperability Standards to Work

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## Abstract

*This paper provides a snapshot of the current interoperability standards landscape and investigates how different standards are adopted in different jurisdictions. The aim is to provide useful insights for decision makers by looking from a wider angle to include political, social and business drivers rather than taking a purely technical approach. Semantic interoperability, which is a major bottleneck to achieving eHealth systemic interoperability, is dependent on terminology, content and messaging standards. In particular, the architectural aspects of content and messaging standards seem to be critical and currently the subject of many heated debates. A considerable amount of effort into international harmonisation is underway and evidence shows that it may be possible to use different standards and yet still be able to accomplish semantic interoperability. It is recommended that a careful analysis be performed to seek evidence, rather than relying on hearsay, for determining how each standard fulfils certain requirements depending on the context. An environmental scan and literature survey highlights the fact that making a good choice of standards depends on what outcomes are desired, and usually involves selection of a number of different standards to be applied together. It is to be noted that, non-technical aspects of standards, such as acceptance, feasibility of implementation or availability of expertise, are as important, and determine what is achievable. The paper concludes by presenting a number of options which include combinations of standards and also provides insights for the evaluation and selection process.*

**Keywords: Electronic Health Records, Interoperability, EHR Standards**

## 1. Introduction

eHealth interoperability at the systems level can be defined as the ability of two or more information systems to exchange both computer interpretable data and human interpretable information and knowledge [1]. It spans multiple levels – from the physical network through data, information and knowledge levels. Currently the major problem in achieving true eHealth systemic interoperability is the lack of semantic interoperability at the layers of information (i.e.

reference information models) and knowledge (i.e. concept models, guidelines). Practically, this means that the precise meaning of exchanged information obtained from one system is understandable by any other system or application, as though the information was created within the first system.

Standards are essential for the development and deployment of interoperable eHealth systems. They ensure that risk is minimized when developing new technology, prevent vendor lock-in, enable re-use of solu-

tions, and eliminate costly custom development and integration [2]. While a multitude of standards exist for eHealth interoperability, Electronic Health Record (EHR) terminology, content and messaging standards have a prime role. However, it takes more than just standards to achieve interoperability at systems level – that is real systems exchanging information seamlessly without losing semantics. In addition to the technical and standardisation challenges, one must also take into consideration leadership, political, organisational,

legal, psychosocial and commercial issues as well as emerging technologies.

In other information technology (IT) sectors with limited breadth and complexity, such as telecommunications and transportation, factors including standardisation of business processes and workflow, availability of implementation guidelines and presence of design tools and reusable software components have been important to achieve global interoperability. Most notably, a movement towards open systems has been the key enabling factor. Open systems promise better software interoperability, portability and maintainability thorough implementation (either open or closed source) of open specifications and standards, and providing well documented interfaces, services and supporting formats [3]. Open Standards, developed collaboratively via a transparent consensus-driven process and governed by not-for-profit organisations, create a fair and competitive market for implementations. The specifications, supporting documents and intellectual property rights are accessible to all free of charge or at a minimal cost to ensure widespread adoption [4]. The mobile phone is a good example in the telecommunications industry. Telecommunication companies rely on open standards to provide their users a wide range of services at any time and at any place. The convenience, accessibility and decreasing costs experienced by mobile phone users have been influential on the acceptance of the concept of openness in the market. The importance of open standards in eHealth has been underpinned in a recent European Union (EU) recommendation on achieving Europe wide interoperability of EHR systems within the context of its eGovernment initiative [1]. The United Kingdom, the Netherlands, Denmark, New Zealand, Malaysia, India and a growing list of other countries now endorse the use of open standards. Furthermore, a more recent report not only articulates this very strongly but also points out the potential of open source software in conjunction with open standards

for achieving better interoperability [5].

There are also important initiatives led by the industry to address issues not covered by standardization bodies and also to provide complementary approaches to existing standards. Integrating the Healthcare Enterprise (IHE) seeks to make better use of existing standards and provides detailed specifications (called IHE Profiles) after elicitation of key use-cases in certain technical and clinical domains. It also performs product compliance testing at carefully planned and supervised events called Connectathons. The Cross-Enterprise Document Sharing (XDS) Integration Profile or IHE XDS defines a standards based document repository and a registry to facilitate sharing of clinical document between organisations. Thus it is considered to be an important and pragmatic mechanism for achieving interoperability [6]. openHealth Tools [7] is an open source platform designed to deliver interoperable solutions established by the collaboration of major stakeholders including some leading vendors in health IT. The interoperability framework and reusable artefacts provided are expected to boost interoperability. A leading group of experts, with the purpose of creating high quality clinical content models, have established a Web based collaboration environment called the Detailed Clinical Models Collaborative [8]. The modelling and sharing of clinical content is aimed to be standards neutral (i.e. they can be used with any of the available interoperability standards).

Internationally there are currently a number of large scale projects each utilising a different set of standards from which important lessons can be learned. This paper presents a brief survey of relevant standards and then reviews international experience. It is mainly focused on standards used in the management of clinical content and messaging; namely Health Level Seven (HL7) Version 2 (v2) and Version 3 (v3) [9] including Clinical Document Architecture (CDA) [10] and Continuity of Care Document (CCD) [11], openEHR [12] and CEN

EN13606 [13]. ISO 13606, which consists of the adopted first three parts of CEN EN13606, is not yet complete and thus not covered. When referring to both standards 13606 shall be used throughout the paper; otherwise the prefixes CEN EN and ISO shall be specified. As an essential element of semantic interoperability, biomedical terminologies are used in conjunction with reference information models and clinical content models [5]. Thus, terminology standards (i.e. SNOMED) and their interplay with the content and messaging standards are underlined; but they have not been investigated individually.

A number of key standards evaluation and classification studies have recently been undertaken. Eichelberg et al [14] surveyed a larger set of interoperability standards and analysed their functionality. The paper concludes that there is no single winner standard and points to the combined use of standards and the importance of harmonisation work. However it is envisaged that in the near future CEN EN13606 and IHE XDS will play an important role and that the option of HL7 v3 with CDA will most probably be unlikely. In Australia, the National E-Health Transition Authority (NEHTA) published a remarkable report [15] to review EHR content standards and recommend the most appropriate standards. It has been suggested to adopt first three parts of CEN EN13606 as content standards and use initially HL7 v2 messaging which will be replaced in future by either HL7 CDA or XML serialisation of CEN EN13606 EHR Extracts. In an effort to develop a map of relevant standards for the national EHR project in Canada (iEHR), more than 160 key health informatics standards were analysed [16]. As the key finding, no particular standard has been identified which would meet all of their requirements. More recently, an inventory of eHealth standards has been prepared as part of a comprehensive report commissioned by the European Commission (EC) which spans many other aspects of eHealth standardisation [17].

This paper is based on a report commissioned by the New Zealand Health Information Strategy Action Committee (HISAC) to inform ongoing developments in health IT infrastructure [18]. New Zealand has a well-established patient identifier system based on the National Health Identifier (NHI) number. The NHI began in 1979 as a master patient index among public hospitals. In more recent years the scheme has been strengthened with enrolment of individuals into Primary Health Organisations (PHOs), and further by a concerted clean-up and management of duplicate NHI numbers

through a New Zealand Health Information Service (NZHIS) initiative in 2004 [19]. New Zealand is noted for internationally top-tier quality and penetration of community-based General Practice computing. [20-21]. HL7 v2 messaging is widely used both among hospital systems and, leveraging the NHI, between hospitals, laboratory testing services and General Practice over integration services, notably the HealthLink network [22]. It was into this landscape that we undertook analysis of the health information standards landscape as presented herein.

## 2. Key Health IT Drivers and Future Trends

Failing to achieve eHealth systems interoperability now presents itself as a significant bottleneck which hinders advances in many aspects of health-care [5]. Revisiting the key health IT drivers given in Box 1, it becomes evident that many of these apply to varying extent to eHealth systemic interoperability as well.

### Box 1 – Key health IT Drivers

**Quality and effectiveness of care delivered:** marked inconsistencies are observed between the management of similar patients, new advances coming too late into practice, and poor investigation of outcomes.

**Patient safety:** significant diagnostic and therapeutic error rates are observed in all jurisdictions.

**Cost of care delivery:** there is a worrying international trend of increasing healthcare costs due to the ageing population, increasing burden of chronic disease, and increasingly expensive care options, and wastage of resources through inappropriate, unnecessary or duplicated interventions.

**Accessibility and equity:** there are serious problems in overall or equal access to healthcare due to waiting lists and affordability, or in some countries where physical accessibility is difficult due to distance, safety or geographic and political factors.

**Shortages of skilled healthcare workers:** leading to the need to enable fewer staff to deliver more care, safely and effectively, and to free staff from mundane administrative tasks.

**Public Health:** a requirement to monitor population health data for biosurveillance and to inform health strategy.

**Sound Biomedical Research:** there is increasing level of demand from pharmaceutical industry and genomic research for the standardisation of clinical data and consolidation with drug and genetic data so as to be able to develop new, more effective and somewhat 'personal' treatments. Linking of 'genotype' and 'phenotype' - meaning the connection between the information in genes to physical/behavioural attributes is only possible by achieving a large-scale EHR having a high level of semantic interoperability.

**Others:** transforming towards an increasingly mobile population, increasing requirement to manage distributed and shared care (i.e. across community from primary to tertiary).

eHealth standards development and selection strategies should address important future trends and new challenges; such as:

**Personal Health Records:** these patient-controlled repositories of health information are becoming a popular notion particularly in the United States amongst employers, insurers and managed care organisations. Notably, even companies previously not focused on healthcare, such

as Google and Microsoft, have launched such offerings.

**Chronic disease management:** there is considerable interest and activity around distributed chronic disease management solutions with the objective of keeping patients out of secondary care facilities, increasing overall wellness and reducing cost of care delivery.

**Home telemonitoring:** there exist examples of large-scale use of remote

monitoring of patients using instrumentation that transmits data back to centralised care centres.

**Telemedicine:** it is already an important part of many national eHealth strategies.

**Decision support:** it is widely seen as the greatest return on investment for eHealth.

**Personalised genomic medicine:** the use of personal genetic informa-

tion in treatment selection is believed to deliver more effective care.

**Biosurveillance and bioterrorism detection:** the ability to access and process standardised health data is essential for early detection of health threats – a very important issue especially in the United States.

**Support for complementary and alternative medicine:** growing in popularity worldwide.

**Future technologies:** choices made now should not preclude graceful migration to as yet unseen future technologies.

### 3. Standards landscape

The adoption patterns and common perceptions encountered during our qualitative research on HL7 v2 and v3, CDA/CCD, CEN EN13606, and openEHR are presented. These arguments have been compiled from multiple sources including interviews and from the long list of references in the

original report [18] as well as the authors’ experience.

#### 3.1. HL7 v2 Messaging

##### General features

Having started in the late 1980s, HL7 defined the second version of its messaging standard. Experience with the early Version 2.1 and 2.2 implementations and an enlarged pool of volunteers led to the development of versions 2.3 through 2.7. HL7 v2 messaging uses a simple, lightweight syntax to deliver point-to-point messages which may trigger a set of well defined events (such as laboratory orders) in a distributed computing environment. The messages lack a formal underlying reference model, and feature considerable optionality in addition to permitting user-defined elements. The optionality and user-defined elements require that interacting parties reach prior agreement on how their messages will be structured and interpreted (“negotiated interoperability”)

before exchanges of information can occur.

##### Adoption

Uptake of HL7 v2 messaging is ubiquitous internationally, and version 2 is seen as a pragmatic and effective solution to point-to-point messaging. The use of its older versions is not uncommon; such as in the United States where laboratory systems often still use v2.1.

HL7 v2.5 is in the final stages of adoption as a full ISO international standard (ISO/HL7 FDIS 27931). There is ongoing work on extending v2 to handle a wider range of clinical care messages and (in Australia) to carry clinical data structured in accordance with openEHR/ 13606 archetypes. If HL7 v2 becomes a full ISO standard, it should be noted that its adoption by any country can be defended against challenges under the World Trade Organization (WTO) Technical Barriers to Trade (TBT) agreement.

Arguments in favour	
	Its data types are richly expressive and it is possible to use v2 messages to pass arbitrary structured objects. As such, existing v2 messaging infrastructure could be used to transport constructs defined in a different, semantically richer, formalism.
	The additional message structure added into later versions of the standard has largely eliminated the need for user-defined message segments.
	The ease of use and pervasive uptake of v2 drives further use and adoption within a low cost vendor service model.
Arguments against	
	Optionality and ambiguity in message interpretation inhibits or prevents large-scale interoperability, as successful exchange of messages requires prior agreement between the parties - “negotiated interoperability”.
	Lack of explicit semantics makes inter-organisational exchange of information difficult; there are no means to identify the semantic content of messages beyond that encoded explicitly in the standard, or to identify the relationships between content.
	Attempts at regional v2 implementation standards have met with limited success.
	It lacks the privacy and consent structures required for a shared EHR.
	v2 is inadequate for clinical observations, as there is no way to express complex, post-coordinated concepts in v2.
	There has been discussion within HL7 of sunsetting v2 messaging in favour of v3.

### 3.2. HL7 v3 Messaging

#### General features

Building on experience with HL7 v2, the HL7 v3 project was launched in the 1990s in order to establish semantic interoperability in loosely coupled systems. At the core of this standard is the Reference Information Model (RIM), which is an object-oriented model from which all specialised HL7 v3 artefacts are derived and from which all HL7 v3 data derive its meaning.

An intention of the v3 RIM is machine computability, which is perceived by some as a significant return on investment for the approach. v3 messages are derived from the RIM, data type specifications, vocabulary domains (including bindings to external vocabularies) and a constraint model, which are applied together to define semantically unambiguous assertions. The domain modelling is built around the notion of actions (the “Acts”) as opposed to documents; as such, there is no distinction made between an action and its documentation.

RIM-derived assertions relevant to a particular context can be aggregated into HL7 Templates (such as a “blood pressure” template aggregating systolic and diastolic pressure, patient posture, and the method used to measure the pressure), and relationships can be expressed between statements. These templates (or “Clinical Statements”) roughly correspond to 13606 or openEHR Archetypes, and to SNOMED CT post-coordination assertions. Unfortunately, because it is possible for data types in Templates to take post-coordinated SNOMED CT expressions as values, the same notion can be expressed in several different ways depending on what portion of the semantics is delegated to the terminology and what portion to the v3 message.

There is considerable ongoing activity in HL7 Technical Committees and Special Interest Groups to refine various aspects of the model and data types, such as constraining terminology bindings and permitted ways of representing various types of

assertion (retaining expressivity with the RIM), and extending the CD data type to express all the qualifiers of a code value.

#### Adoption

Accurate statistics on the prevalence of HL7 v3 are difficult to source. While HL7 working groups are well attended by members from over thirty countries, the society does not maintain statistics of the adoption of the standards. Governments in the Netherlands, Canada and the United Kingdom have made strong statements toward the adoption of HL7 v3 but few applications have actually been implemented.

Internationally, HL7 v3 messaging skills are scarce, but despite this, significant progress appears to be happening, particularly in the public health space. It should be noted that HL7 v3 RIM has been adopted as a full ISO international standard (ISO/HL7 21731:2006). Therefore its adoption by any country can be defended against challenges under the WTO TBT agreement.

#### United States

Though widely adopting HL7 v2, the US lags well behind in adoption of HL7 v3, and most if not all significant uptake is by government agencies. Key examples include the Food and Drug Administration (FDA) requiring v3 for submission of all drug labels, and moving towards v3 for adverse event reporting; National Cancer Institute (NCI) using v3 in its BRIDG model; and the Centers for Disease Control and Prevention (CDC) where examples include applying v3 structured documents to healthcare-acquired infections, and a decision support pilot based on a v3 ontology. Interestingly, v3 is starting to be applied as a healthcare information model in the back end, with some institutions adopting the RIM as a database model. However, only two or three vendors have produced v3-based offerings.

v2 users often express uncertainty as to when to move to v3. Current HL7 v2 US-centric vendors are generally in a “wait-and-see” mode, until their customers (hospitals, clinics,

labs, imaging centres) or regulatory agencies demand it.

#### Canada

Through its USD \$2.1 billion infrastructure investment programme (with also major additional funding from provinces) managed by Canada Health Infoway, Canada intends to lead the development of HL7 v3 as the messaging standard for the transmission of the individual electronic health record, iEHR. Infoway has adopted a message-centric approach for its pan-Canadian iEHR, and has defined standards for registries, clinical messaging, public health, diagnostic imaging, drugs, laboratory, and claims. Communication with the central hub (“HIAL”) in each Province is required to be through v3 messages, but point of service systems are not required to migrate from their existing internal v2 messages.

#### United Kingdom

The National Health Service (NHS) Connecting for Health (CfH) has implemented a system that is based on v3 messages and CDA on their national infrastructure Spine. In order to develop v3 structures they have borrowed the archetype modelling formalism from openEHR and heavily engaged Open Health Tools.

Initially, all messaging on the Spine was intended to be done using v3 messages including clinical content. Although there is now a huge volume of v3 messages travelling on the Spine every day (largely administrative and prescription data), most of the message framework development is now complete and that specialised clinical content is now being defined as UK-customised template-constrained CDA documents wrapped in v3 messages. However local systems continue to operate with their existing HL7 v2 infrastructure but must use v3 when interacting with the Spine.

An important aspect of the NHS experience is their discovery of a need to impose requirements on persistence of clinical information by vendors. Their programme was initially 100% focused on messaging, but it became apparent that some vendors were unable to populate parts of messages because of inadequately

expressive data models. As a consequence, currently only medications, allergies and adverse reactions are mandated, but there are plans to extend this as the supplier community matures.

**The Netherlands**

The Netherlands has a national infrastructure, called AORTA, which uses v3 messages for data exchange between healthcare providers. In this architecture, all data are held in the

source systems, and a central hub acts as a broker for data requests. All interactions with the central hub are done using v3 messages, but source systems do not necessarily use v3 messaging. There are messages implemented for patient summary and medication lists. However the pilot implementations proved that the complete system is brittle and expensive to implement. After years only 30-50 users have systems that function.

There are also regional implementations using the v3 standards, but the national central hub infrastructure is not completed.

**Australia**

NEHTA has recommended the continued use of HL7 v2 augmented with CDA for the short term and the adoption HL7 V3 in the longer term; but there are yet no implementations.

Arguments in favour	
	It is rich in clinical semantics, and capable of expressing the whole domain of healthcare.
	The specifications address many of the practical difficulties with real world medical information (such as incomplete information, uncertainty, duplicate records).
	The RIM does provide means for describing physical reality, but leaves the definition of this content to special interest groups, often in the form of terminologies or ontologies.
	Significant tooling has been developed.
	It is capable of supporting advanced decision support and automated reasoning.
	“Most of the work being done in clinical care (in the US) is being done in v3.”
	v3 is “not that complex once you get into it”, that most people do not require its full complexity, and that the dynamic model is no more complex than v2.
Arguments against	
	Even within the HL7 world, there are those who feel uncertain about the fitness for purpose of v3.
	v3 does not confer substantial advantages over v2 for simple alerting, drug interaction checking, recall systems, best practice guidelines, clinical pathways, and so forth. It's not clear where the return on investment is.
	The standard is in a constant state of change, despite the release of the “normative” version in 2005.
	The message structures are very complex and difficult to understand; the learning curve is very steep, and skills are in critically short supply.
	It can't be assumed that v2-v3 mapping can be done at the integration engine layer, because whilst the mappings are straightforward, the problems lie with the application's behaviour as the dynamic behaviour and trigger events of the two standards are quite different.
	It's much harder to receive v3 artefacts than to send them, as getting the semantics right at the receiving end takes a lot of effort.
	The RIM is plagued with inconsistencies between an Information Model (objects document things) interpretation and a Reference Ontology (objects are things) interpretation.

The RIM confuses acts with records, and documents themselves are hardly modelled or structured. There are no hierarchies in documents, no formal model to define relationships between documents, and no means to express data in its clinical context.
There are illogical definitions, and an absence of familiar clinical concepts such as “diagnosis”, “assessment” and “prognosis”.
Information held in documents (CDA) is treated differently from information held in messages, in that CDA documents are permitted to make factual assertions (albeit in narrative) whereas v3 messages must make indirect assertions via Observation Acts.
v3 is not suitable as a model for retention of EHR information, and in fact HL7 does not specify an EHR Architecture (the HL7 EHR Functional Requirements specification is not an EHR specification, it is a reference list of functions).
The information content of v3 XML is low (under 5%) and the messages are very large.
The complexity of the model, and its interaction with external vocabularies such as SNOMED CT, means that there are many ways to express the same assertion, and no adequate mechanism for ensuring that systems consuming such messages will interpret the information in the same way.
The semantics of the information content of the message are mixed in with the semantics of the message itself.
It is unclear how one might query a repository of v3 messages.
The basic design of HL7 v3 is closer to a workflow language than to a documentation language. This creates a dependency between documentation and workflow, the content of documents becoming limited by the associated workflow requirements.
Implementing messages need a lot of resources. They have to be implemented in all communicating systems in the same way; once implemented message cannot easily be adapted for local use.

### 3.3. CDA and CCD

#### General features

CDA is an approved ANSI/HL7 standard for an HL7 v3 artefact that specifies the syntax and semantics for a clinical document. Unlike v3 messages, it is intended to be persistent and human-readable, representing something equivalent to a signed paper document.

The CDA document consists of a header (containing metadata expressed in v3 structure) and a body. The second and current version of CDA r2 provides “incremental” semantic interoperability within the body by allowing three different levels of increasing structure and markup. In this way adopters can create unstructured “level 1” documents

and over time increase the sophistication of the structured representation of the document content until “level 3” documents are achieved.

A specific implementation of CDA is the Continuity of Care Document (CCD) which is the application of the Continuity of Care Record (CCR) as a constraint on CDA r2. CCR, an ASTM standard, is essentially a data set specification for the aggregation of all of the pertinent data about a patient and transfer of that information to another provider. CCD is the expression of CCR as a type of CDA document. It is important to note that CCR is not a progress note, discharge summary, procedural note or laboratory results form. It is a summary “snapshot” of the patient’s health at a point in time, some or all of the infor-

mation originating in other documents.

As with HL7 v3 messaging, CDA skills are scarce, and the total cost of ownership of a CDA implementation is largely unknown.

#### Adoption

CDA is widely implemented internationally, and IHE has defined a relevant Profile. Many practical applications of CDA for EHR are based on construction of a “virtual EHR” through use of CDA (plus DICOM and potentially other standards) with IHE XDS.

HL7 CDA r2 is well on its way to being accepted as a full international standard (ISO/HL7 27932 Data Exchange Standards Clinical Document Architecture, Release 2). It has passed the initial DIS (Draft Interna-

tional Standard) ballot in June 2008 and is now in the process of final approval.

**United Kingdom**

NHS CfH has made extensive use of CDA and sees it as a route to fuller coding of clinical data as their national infrastructure Spine develops. Though originally designed just to hold coded data, their requirement is now for the Spine's central EHR repository to be a CDA store and for suppliers to code medications, allergies and adverse reactions as a minimum. Suppliers to CfH have expressed commitment, and tooling has been developed (focusing on open source) in association with the HL7 Tooling Collaborative and with Eclipse Healthcare.

**United States**

CDA is used extensively for the transfer of mainly administrative health information between the Regional Health Information Organizations. In addition, several academic healthcare providers and research institutes utilise CDA for the docu-

mentation and exchange of clinical information. Most notably, Mayo Clinic depends on CDA technology for clinical documentation.

**Canada**

e-MS project in the district of British Columbia uses CDA for medical summaries. It is also under consideration for widespread use in their national iEHR project.

**Finland**

Like the US, health information is transferred between regional organisations via exchange of CDA documents. It is also used in ePrescription services and for the generation of numerous clinical documents and data collection using online forms.

**France**

The national pharmacy system is underpinned by CDA/v3 messaging. Also the DMP Project, which is an effort to define a national eHealth record, is based on CDA and IHE.

**Germany**

The SCIPHOX project, focusing on the exchange of medical documentation between hospitals and the outpa-

tient area, adopted CDA in its successive phases.

**Austria**

The ELGA initiative, a plan for implementing a nationwide EHR system, makes use of CDA together with DICOM and some relevant IHE profiles.

**Greece**

Combining ECG data with the CDA based health record via external links has been examined in the HYGEIAnet Project in Crete. WebOnColl, a healthcare specific collaboration tool, also makes use of CDA.

**Argentina**

Hospital Italiano de Buenos Aires uses CDA and HL7 v2 messaging in its hospital information system.

**Japan**

The MERIT-9 document standard which is employed in the Shizuoka Prefecture EHR project uses CDA r2 for clinical referrals with pointers to clinical contents.

Arguments in favour	
	It provides a readily understood and familiar structure, the signed document.
	It provides an attestable and non-repudiable form of documentation that is well understood, again the signed document.
	It provides a means for representing text alongside coding.
	It is a stable and flexible standard for developing communications with coded information.
	It provides a pathway from narrative free text documents through incrementally coded data to fully coded and semantically interoperable clinical data.
Arguments against	
	It has not demonstrated a return on investment.
	Criticism of CDA r2 Level 1 otherwise appears sparse, whereas CDA r2 Levels 2 and 3 are subject to similar criticisms as HL7 v3 messaging
	It is not designed for implementing a full-blown EHR system.
	There is no mechanism for reconciliation of different versions of the same information.
	Its expressivity is limited with HL7 v3 RIM.

### 3.4. OpenEHR

#### General features

OpenEHR Foundation is not a formal standardisation body but develops specifications for implementing a full EHR System. Persistence is more pronounced as opposed to messaging. At the heart of its methodology is the Archetype paradigm which is a formal constraint based content model. Each archetype describes configurations of data instances whose classes are defined in a reference model.

openEHR assumes that a lifelong, longitudinal, patient centred, secure and shareable EHR cannot be realised by aggregation of messages and that a high level of interoperability can only be realized by means of engaging standardized clinical content models (called Archetypes), a stable reference model and semantically rich terminologies. openEHR Templates are higher level constructs which use Archetypes and further constrain them for particular use. They combine a set of archetypes, terminologies, language and other details for local use. Templates can be used for designing screen forms and also as persistence models, mapping models to legacy systems, documentation models and definitions for software objects. Persisted EHR data can be readily queried using a special query language that applies constraints to path descriptions through the hierarchical structure of the openEHR composition and its contents.

Since the release of first version of the openEHR specifications in the beginning of circa 2006, the reference models in successive releases proved to be very stable, requiring only minimal changes which were all backwards compatible.

A compliance test against the ISO 18308 [23] architectural requirements has already been performed for the openEHR reference model and a mapping document is available.

#### Adoption

Worldwide, interest in openEHR is spreading. CEN adopted a subset of

the openEHR specifications, including the archetype formalism, as the basis of the European EN13606 standard which has gone on to become an ISO standard in 2008 through the final approval of ISO 13606 Parts 1 to 3. However due to evolution of the openEHR specifications there are subtle differences between the current openEHR models and those endorsed by the EN and ISO standards. There is an increasing number of full or partial implementations of the openEHR specifications; predominantly open source projects. openEHR is a prominent actor in Open Health Tools project. There are also active negotiations between the openEHR Foundation and the International Health Terminology Standards Development Organisation (IHTSDO) for common modelling and governance of clinical terms and concepts. The openEHR approach is now part of Microsoft's Connected Health Framework.

#### United Kingdom

NHS CfH has adopted Archetype formalism for capturing clinical content specifications. Nearly 1000 archetypes have been currently developed.

#### Sweden

openEHR Archetype formalism has been adopted by the national EHR platform within a broader standards-based approach that includes elements of CEN EN 13606, HL7, HISA and ContSys. The Java implementation of openEHR is led from Sweden and openEHR is seen as the implementation pathway.

#### Australia

Two implementations in primary care are underway. The Cancer Council of Victoria long term clinical research repository is openEHR based. NEHTA has begun a project to express structured reporting in anatomic pathology using openEHR archetypes and templates. The .Net implementation of openEHR is led from Australia.

#### Denmark

A national proof-of-concept project is underway, as are regional evaluations of the openEHR archetype formalism.

#### The Netherlands

A large teaching hospital (Alkmaar) is currently implementing an openEHR based information system. A diabetic management project is also using openEHR methodology. There is growing vendor interest, especially towards solutions for integration between openEHR/13606 repositories and their national eHealth programme which uses HL7 v3.

#### Singapore

The clinical content for the national EHR program is being specified using openEHR archetypes.

#### USA

The American College of Rheumatologists has decided to express its clinical content specifications using openEHR archetypes. There is growing interest from vendors. The Python implementation of openEHR is led from the US.

#### Japan

There is a Japanese website and trail implementations at two universities. The Ruby implementation of openEHR is led from Japan.

#### Brazil

There is interest from the government. A Brazilian vendor has developed an HIS which is a Java implementation of openEHR.

#### Scotland

The archetype formalism is being evaluated for clinical content modelling.

#### Turkey

Although their national HIS project is based on HL7, openEHR has been evaluated in several national and international projects. A vendor has been actively involved in medical device data integration using openEHR Archetypes. There is a considerable amount of activity on semantic interoperability (especially on HL7 and openEHR) at the Middle East Technical University (METU).

Arguments in favour	
	The model is intuitive and easy to understand for clinicians. They generally find reading, discussing and designing archetypes relatively straightforward. The terms used are accessible and easily mapped to general clinical recording practice.
	The approach is designed to record observations and to query those observations.
	The model is fully compliant with ISO/TS 13808.
	Extracts can be transmitted within HL7 v2 messages.
	As the domain-specific semantics are in the (declarative) archetypes and vocabularies, the reference model should be stable over time.
	Archetypes have been transformed into compliant CDA documents via XSLT transformation.
Arguments against	
	The approach lacks semantic rigor and does not contain a logically sound ontology. The reference model does not provide a full basis for semantic interoperability – a separate model is required to represent detailed clinical semantics and cross-concept linkage.
	The approach does not describe knowledge in a way that can be reasoned against. It works well for simple scenarios, but does not adequately handle complexity. It is “just not adequate to do healthcare, from a machine processing perspective”.
	It does not provide strong support for semantic linkages across archetypes, and within an archetype semantic detail is dictated by the archetype authors.
	There is no experience with the approach in medium to large-scale systems.
	Uptake has been extremely low, despite years of work.
	It is an unstable specification, subject to significant change.
	It is a challenge to create consistent, non-overlapping and intelligently inter-linked models; better tooling than those currently available would be required for a national repository to avoid semantic redundancies and conflicts.
	Present governance of the openEHR Foundation, if viewed as an SDO, is relatively weak.

### 3.5. CEN EN13606

#### General features

CEN EN13606 is a five part European standard the goal of which is to enable exchange of health records between systems. It contains a reference model for defining an “EHR Extract” and for messaging such an extract. It does not attempt to describe a full EHR system. It has the Archetype formalism and a document-cen-

tric reference model that is based on, but much simpler than, openEHR.

CEN EN13606 has been under concentrated review recently by ISO, and the following core parts have been adopted as full International Standards:

- 1) ISO 13606-1:2008 Health informatics – Electronic health record communication -- Part 1: Reference model (published February 7, 2008).
- 2) ISO 13606-2:2008 Health informatics – Electronic health record communication -- Part 2: Archetype interchange specification (published November 25, 2008).
- 3) ISO 13606-3:2009 Health informatics – Electronic health record communication -- Part 3: Reference archetypes and term list (published January 14, 2009).
- 4) Part 4 (Security) is in Committee Draft stage on its way to become

ing an ISO Technical Specification; however, it is not essential for adoption of 13606.

- 5) Part 5 (Interface specification) is available as a draft international standard: ISO/DIS 13606-5 and is also not essential for adoption of 13606. The delay in production of Part 5 has been partly due to issues of harmonization with HL7v3.

One issue for ISO 13606 is that it still specifies the previous CEN data types but is expected to be amended to call up the harmonized ISO/CEN/HL7 data types once ISO 21090

Health Informatics Harmonized data types for information interchange passes final FDIS ballot in ISO (and CEN) and parallel ballot for approval as an ANSI/HL7 normative standard.

**Adoption**

NHS looked carefully at it and chose to make use of CEN EN13606 augmented with certain extensions from openEHR. Currently there appear to be only a small number of projects using CEN EN13606, and also the perception that openEHR is the implementation pathway to CEN EN13606. However epSOS, a large project involving 12 European countries supported by the EC, will possi-

bly utilise CEN EN13606 for implementing patient summary and medication records across borders. Serbia has also prepared a national EHR project.

Since the core operative parts of CEN EN13606 have been adopted as a full ISO international standard, its deployment by any country can be defended against challenges under the WTO TBT agreement. This is an important point and there have been cases, particularly in Germany and The Netherlands, that the adoption of openEHR and/or CEN EN13606 was opposed on the legal grounds.

Arguments against	
	The reference model of CEN EN13606 cannot in itself provide a full basis for semantic interoperability.
	There are few examples of its implementation.
	openEHR is a superset of the standard with significantly greater capabilities.
	It provides no constraints on what can be defined in an archetype; and there are problems with location specification for search.

**3.6. Trends in standards adoptions**

There appears to be a number of options, with possible combinations of standards, which are being adopted

in differing scenarios. The combinations appear to be evolving to allow both messaging and persistence to a greater or lesser extent. In situations where eHealth systemic interoperability would yield a greater return on

investment (ROI), then the options which ensure a higher level of semantic interoperability are being adopted. Some of the options being proposed or adopted with their pros and cons are summarised in Table 1.

	Pros	Cons
<b>HL7 v2 Messaging + CDA</b>	<p>Allows use of existing messaging systems where ROI on upgrading is not established.</p> <p>CDA would offer limited data-set persistent storage solutions.</p> <p>Some degree of interoperability due to the vocabulary bindings in coded message fields.</p>	<p>Limited semantic interoperability of messaging.</p> <p>Inability to express context of messages.</p>

<p><b>HL7 v3 Messaging + CDA</b></p>	<p>Allows for high level of semantic interoperability.</p> <p>May offer a ROI in certain situations where decision support tools are to be implemented based on the content of the messages.</p>	<p>ROI for upgrading messaging systems would need to be established first.</p> <p>Cost of development using a relatively unstable RIM may be high.</p>
<p><b>HL7 v2 Messaging + openEHR/ 13606</b></p>	<p>openEHR may offer a full semantically coherent and persistent solution within an organisation.</p> <p>Communicating with outside organisations using HL7v2 would offer a pragmatic solution to messaging as the integration infrastructure and skills already exist, so the total cost of ownership is low.</p>	<p>There is currently little evidence for the ROI of such a solution.</p>
<p><b>openEHR/ 13606 Archetypes + HL7 Templates in CDA</b></p>	<p>Archetypes appear to be gaining acceptance as a way of modelling clinical content.</p> <p>While not adopting a full openEHR solution, applying the archetypes to HL7 templates would make the CDAs more in line with clinical needs.</p>	<p>This is more a methodology rather than a technology solution.</p> <p>The technology is still CDA/v3. It does not implement the openEHR reference model or data types; it just uses the archetype methodology for content creation.</p>
<p><b>Pure openEHR Implementation</b></p>	<p>Allows building of an EHR infrastructure having a high level of semantic coherence.</p> <p>Good persistence and querying mechanism.</p> <p>Empowerment of clinical domain experts and effective clinical content governance.</p> <p>Future-proof; significant savings during maintenance and greater portability.</p>	<p>There is only scarce experience in a full openEHR implementation and it brings a paradigm change to how we design and develop software.</p> <p>There are not many experts and development tools/libraries/best practices are needed.</p> <p>It is unclear how the health information will be exchanged in a heterogeneous and distributed environment.</p> <p>Migration or integration is needed for most of the existing systems to realize total benefits. This may incur very high switching costs.</p>

**Table 1:** Some of the options for standards adoption

### 3.7. Harmonization Efforts

In the year 2000, CEN and HL7 signed a Memorandum of Understanding to enable further co-operation between the two organisations, with particular emphasis on harmonisation and, where possible, convergence. Until then significant amount of harmonisation work had already been underway so as to address the overlaps, gaps and counter-productive efforts. The Joint Initiative on SDO Global Health Informatics Standardization (JI) has now been established after signing of the Joint

Initiative Charter by CEN, ISO and HL7 in August 2007. Recently, the IHTSDO and CDISC (Clinical Data Interchange Standards Consortium) have joined the JI. Various activities including balloting for key standards are being carried out collaboratively by the Joint Working Group hosted by ISO/TC 215 and co-chaired by representatives of CEN/TC 251, ISO/TC 215 and HL7. Moreover, many CEN/TC251 committee members are also active in ISO/TC 215 and almost all group meetings are now being held jointly. It is believed that standardisation through such international col-

laboration and strong leadership will result in better standards with global applicability.

It is also worth mentioning the EC Mandate M/403 to coordinate activities of the different European standardization bodies. Coming into effect in circa 2007, this mandate brought together many international SDOs, including HL7 and IHE.

Current areas of harmonisation include:

- Data types harmonisation between CEN EN13606 and HL7.

- Further work to align 13606 with the forthcoming ISO Health Data Type Standard (ISO 21090, presently a Draft International Standard).
- An implementation guide to enable 13606 EHR Extracts to be communicated within HL7 v3 messages.
- Mapping of the 13606 Reference Model to HL7 v3 RIM and CDA r2.
- Reference Archetypes that model HL7 v3 structures in 13606.
- An EHR Extract D-MIM that models a 13606 extract in HL7 v3.

Moreover, considerable work has been done to reconcile the openEHR data types with the HL7 data types, and reconciling openEHR structures with HL7 v3 structures.

### 3.8. Conformance

Any standard requires processes for the regulation of conformity to the standard. For example, W3C makes available an HTML validator program that automatically determines conformance of a Web page to the HTML standard. In a similar vein, the Australian Health Messaging Laboratory [24] provides a facility where developers can ascertain the level of conformity of their messages with the HL7 v2 standard.

Processes or procedures to ascertain the level of conformity are important to encourage conformance but the regulation of adherence to the standard requires stronger mechanisms for effective regulation. Lessig [25] identifies four types of mechanisms that regulate social behaviour: the law, market forces, social norms and natural phenomena. A simple example illustrates these mechanisms. Motor vehicle speed may be regulated using laws, by advertising to change social norms and increasing fuel taxes to provide an economic disincentive. Motor vehicle speed may also be regulated with the installation of speed bumps as a natural barrier. The regulation of conformance to the HL7 standard in Australia illustrates that, by recommending adherence to HL7 v2 in the short term and v3 in the

long term, NEHTA has deployed something of a weak legal constraint because transgression does not attract legal sanctions. Promotional campaigns to encourage adherence to the standard amongst vendors are mounted by HL7, NEHTA and others, yet this also is a weak constraint. Natural barriers in the form of technologies that enforce strict adherence to HL7 do not exist. Economic factors often work against standardisation as vendors often have financial incentives to depart from the standard or implement only a small part of the standard.

Legal, economic, social and technological strategies to encourage the appropriate conformance to a standard are applicable to any standard adopted. Discussions on governance structures for a standard are arguably as important as discussions about the appropriate choice of standard.

## 4. Interoperability and EHR architecture

eHealth interoperability is largely determined by the EHR architecture. In fact before the term interoperability became a common buzzword, the term “architectural mismatch” was commonly used [26]. Architecture describes the system to be designed, its objectives, its elements, their interrelationships and functionalities [27]. ISO 18308 defines EHR Architecture as “the generic structural components from which all EHRs are built, defined in terms of an information model”. More specifically EHR architecture describes a model of generic properties required for any EHR for providing communicable, comprehensive, useful, effective and legally binding records that preserve their integrity over time, independent of platforms and systems, as well as of national and cultural boundaries.

eHealth interoperability standards beyond data level can be broadly classified into content, messaging and terminology categories. In fact this pattern is repeated in other domains such as marine industry [28] where meta-data standards are separated into

three categories: content standards, transport protocols and vocabularies. Essentially each content standard prescribes a particular EHR architecture which in turn also has considerable effects on messaging. This is due to the “impedance mismatch” between different EHR architectures – that is it is sometimes not possible to transform clinical information without losing semantics conforming to a particular architecture from one into the other. Since it is essential that the semantics of clinical information has to be faithfully preserved within the messages, it can be said that content standards come with their “native” messaging options. The approach of openEHR and 13606 is dramatically different from that of HL7 on health information exchange. While HL7 packs clinical information stored in different representation schemes into a number of semantically coherent messages, openEHR and 13606 both use an EHR Extract mechanism in which parts of EHR can be simply exchanged assuming that each communicating system conforms to the same or equivalent reference model and set of archetypes.

Semantic interoperability is not an all or nothing paradigm. As per requirements of a particular implementation, its degree may change depending on the level of agreement on key elements such as terminology and information and content models [29-30]. Provision of appropriate semantics is divided between the terminology (i.e. SNOMED) and the other elements (i.e. HL7 RIM, openEHR reference models and archetypes/templates). The choice of how much of the semantic representation and complexity will be assigned to different elements is an architectural issue. This is where HL7 and openEHR / 13606 differ significantly. Practically a clinical terminology (or ontology) consists of the description and hierarchy of real world concepts provided with rich semantics in the form of computable links of different types between these concepts. Reference (information) models (ideally) contain stable and fundamental structure and semantics of clinical infor-

mation (i.e. a clinical observation). Content models, on the other hand, cover the informational aspects which are not as stable due to the variability and high rate of change of the domain knowledge which it depends upon (i.e. formal description of physical examination or prescription) [31]. This distinction is made explicit in the openEHR and 13606 architectures. Both standards delegate most of the semantics to the external terminologies by means of logical references called term bindings which act as a bridge between terminology and archetypes. However experience with content models and terminology bindings have indicated that, due to the large number of various models created, a new type of ontology is needed for recording the metadata related with the environment these models are used in (i.e. what type of model, its function in the care process, what part of the EHR, localisation in space and time and so on).

It is interesting to note that while HL7 v3 is moving towards handling clinical content - thus becoming a full architectural standard [27], openEHR is also working on an efficient mechanism to generate various kinds of messages including HL7 v2 and v3. Here an XML construct (Template Data Schema) which consolidates the information model and set of archetypes into a 'classic' XML schema can be used for data entry, data integration as well as message generation. As an example, for a health record summary, CCR, HL7 CCD, CDA R1 and R2, PDF and HL7 v2 artefacts can now be generated automatically [32].

Standards in general tend to be evidence based; i.e. before a new treatment method or protocol is promulgated as a standard approach, there needs to be a reasonable (not necessarily extensive) set of formal evaluations of that method or technique using scientific methods. That solid evidence base seems to be lacking in eHealth interoperability standards. However, one might argue that performing extensive evaluation studies might not be feasible or could not be completed in a reasonable time. So

the only options are using collective expert opinion and looking at relevant evidence from other implementations and ongoing projects. Depending on particular health IT drivers, it is important first to make explicit what the standard has to deliver. Next specific requirements can be elicited and then a pragmatic approach can be taken for assessing whether the evidence applies to own setting and fulfils these requirements.

With regard to interoperability, while the evaluation of most features of the available content and messaging standards are relatively easy and straightforward, the evaluation of architectural aspects needs special attention. This is in part due to its large contribution towards interoperability but it is mostly due to the possibility of conducting better evaluation studies by using published and widely accepted EHR requirements. It is only natural to assume that content and messaging standards should first meet universal EHR architecture requirements. A considerable number of studies have been conducted for the identification of such requirements – most notably the work resulting in the ISO 18308 technical specification depicting a universally applicable set of requirements for EHR architectures. We suggest that an evaluation study be designed where architectural aspects of these standards will be verified against the EHR requirements (from ISO 18308 and others).

## 5. Discussion

The variance in national strategies and major new implementations makes it clear that there is no simple answer. While there is little debate on SNOMED's importance and its leading position as a terminology standard, the dominant architectural standards and specifications for interoperability are HL7 v3 (including CDA) and openEHR/13606; but neither can be classed as 'superior' without significant qualification. However it should be noted that 13606 is primarily intended to support the generic communication of EHR data and

archetypes between heterogeneous EHR systems as opposed to defining a full-blown EHR. Thus it can be thought of as a simplified set of the openEHR specifications used for defining EHR extracts for the purposes record summary and exchange.

eHealth systemic interoperability depends on using a common EHR architecture for the information objects which are exchanged, but this architecture can and should be both technology and domain independent. EHR architecture requirements consist of both domain specific, somewhat technical functional requirements and non-functional requirements informed mostly by economic, political and social health IT drivers. Hence it is no surprise that ISO 18308 addresses most of the key health IT drivers previously listed. Nevertheless it should be noted that whilst architectural aspects of standards may be informed by ISO 18308 and so forth, the adoption of a particular standard is primarily based on how well it meets the needs of the health IT drivers as a whole. Non architectural aspects and features are determined by two factors: 1) Non-architectural requirements (of eHealth Systems) and 2) Factors resulting from the architecture itself (i.e. business constraints and political preferences). An example of the former is a requirement related to the accessibility of standard documents. A requirement depicting the licensing model of the standard may be prescribed by political and business related issues, which is can be given as an example for the latter. A more relevant example to the latter is perhaps the case when a country decides to go for openEHR/13606. There will be lack of experts in archetype based multi-level modelling and development, whereas there might already be a substantial number of HL7 experts. Then the decision may be affected by this factor which is directly related with the architecture itself. There are many architectural questions remaining open, and the appropriateness of standards is surely impacted by that debate. In looking for answers, refer-

ring back to the Health IT drivers might be a sensible approach.

The technical arguments for and against HL7 v3 and openEHR are complex and sophisticated, covering such issues as to the degree which automated machine reasoning can execute on each model, querying data, and the degree to which humans can understand content created using each formalism. Further, neither constitutes a complete solution – the HL7 v3 standard is focused on messaging, whereas the openEHR specifications are focused on persistence which introduces features required for storage of data in an EHR, and is silent on messaging. Although openEHR specifies the content of messages in the EHR Extract, it currently lacks a formal serialisation specification for messaging content, and lacks a dynamic messaging model and therefore doesn't seem to perform well in a distributed heterogeneous environment.

Some of the most advanced infrastructures (notably, the national backbones of the UK NHS CfH, pan-Canadian i-EHR and the Netherlands AORTA) have embraced HL7 v3 messaging and CDA, but there is significant and increasing interest in appropriate roles for openEHR, even in those jurisdictions that have embarked on HL7 v3 implementations.

HL7v2 is in widespread use, with IHE profiles supporting many common interoperability use cases. What is clear is that semantic interoperability is required if the benefits of interoperable eHealth systems are to be fully realised, and that existing HL7 v2 implementations will be unable to deliver on the required standardisation around a reference model, terminologies, data types, composition mechanisms and messaging. However achieving full semantic interoperability in all application areas is neither necessary nor achievable without solid business cases; therefore a holistic EHR approach (virtual, distributed or a mix) is perhaps over ambitious for now. Thus it is envisaged that eHealth systems interopera-

bility be introduced step by step with increasing levels.

HL7 v3, openEHR and 13606 all continue to evolve, and significant harmonisation work is underway. However one should not expect a one to one correspondence between the standards – in fact each standard addresses a different area in the interoperability space. There is, thus, uncertainty about the future of all the alternative existing approaches, but the ongoing harmonisation work may see convergence into a single conceptual framework. This may suggest a “wait and see” approach to policy formation and infrastructure deployment, and indeed this is apparent in the US market where HL7 v2 continues to dominate and implementations of v3 are primarily in the public health sector and for niche applications (such as FDA drug labels).

The NHS CfH experience shows that a pure messaging approach is insufficient without imposing requirements on what data is stored in EHR systems (i.e. ensuring that persisted data is sufficiently expressive to support the required messaging). Immaturity of vendor systems in this regard serves as a barrier to adoption of advanced messaging. Approaches constraining persistence favour openEHR, or HL7 CDA augmented with HL7 Templates (possibly derived from openEHR/13606 Archetypes) – leading in part to the growing international interest in the openEHR specifications. Interoperability based on either of these approaches will require considerable standards content development work (agreed Templates or Archetypes), and ideally this work would be the output of international collaboration grounded in a robust governance process. Many believe that IHTSDO and the openEHR foundation are much more likely to provide such a program together.

CDA is also attracting considerable interest internationally, and is seen by many as supporting a path of incremental semantic interoperability from legacy binary content (such as free text and PDF documents) with a computable document header through to

fully semantically encoded clinical data. Specific CDA applications of interest have been the representation of the ASTM CCR dataset (as a CCD document), the embedding of openEHR archetypes within CDA documents, and the generation of compliant CDA documents from within openEHR systems.

Messaging beyond HL7 v2 requires consideration of both data payload and workflow. It should not be assumed that alternatives to HL7 v2 can be simply mapped to and from v2 messages, as the expected system behaviour associated with the messages can vary greatly. This may or may not be of significance, depending on specific system requirements, but may result in deployment conferring significant infrastructure and retooling costs. In contrast, where the dynamic behaviour of HL7 v2 messaging is sufficient, it has been demonstrated in Australia that structured objects derived from other formalisms can be passed within v2 messages using existing interfacing infrastructure.

One can take a short-cut on the road to eHealth system interoperability if one is willing to emulate the decision of Kaiser Permanente and lock into a ‘monolithic’ single-vendor solution. This is not to say that such a solution is either cheap or trivial (standardisation in terminology and ways of working are still required). It must also be noted that these systems are not in fact monolithic – they will always need to interface and integrate with a myriad of smaller satellite systems. However it is evident that this option is not considered in jurisdictions where there are already existing eHealth systems. Therefore a strategy is implied that enables standards based and open health IT market to deliver on eHealth interoperability requirements.

There is now marked expectation about the use of open source health IT solutions for better interoperability. However, despite the many merits of open source software, without the use of open standards and good documentation, it would be no different to any other propriety system where the

information model is reinvented, not sustainable and therefore will cost more in the long term.

Although demonstration of the benefits of eHealth systemic interoperability has already begun in some countries (such as those reported by Canada Health Infoway), broad proven benefits are not yet in place. Therefore a sound demonstration of the benefit of migration from legacy to interoperable systems is essential to be able to justify national or regional eHealth programs.

## 6. Conclusion

There appears to be a significant amount of gaps, overlaps and competition among different eHealth interoperability standards. A number of possible combinations of standards are being adopted globally. Evidence should be sought on how each standard fulfils requirements related with a diverse set of business cases and scenarios to achieve eHealth systemic interoperability. Proper selection of standards depends on what is desired, and most choices are not mutually exclusive. Thus it makes sense not choosing just a single 'right' option; rather the solution will usually be a medley.

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