NHS Connecting for Health	**NHS-CFH Terminology Binding Requirements**			
	Programme	NPFIT	**Document Record ID Key**	
	Sub-Prog / Project	Technology Office	<Insert Document Record ID Key>	
	Prog. Director	P. Jones	Status	Draft
	Owner	K. Lunn	Version	V0.2
	Lead author/Editor	D. Markwell	Version Date	2008-03-07

Terminology Binding Requirements and Principles

Amendment History:

Version	Date	Amendment History
0.1	2007-11-09	First draft outline for comment. 'Terminology Requirements'
0.2	2008-03-07	Revised with incorporation of material from other draft documents and new material as draft deliverable. Renamed 'Terminology Binding Requirements and Principles'

Report contributors:

Name	Title / Responsibility
D. Markwell	Principal Consultant, The Clinical Information Consultancy Ltd

Reviewers:

Technical Review Group:

Name	Comments received from
Members of the NHS CFH Electronic Health Record Content Technical Advisory Group	

Approvals:

Name	Title / Responsibility	Approval Status	Date	Version
L. Sato	Informatics Standards Lead, Data Standards & Products			
K. Lunn	Head, Data Standards & Products			

Distribution:

Once approved, this document will be publicly available.

Document Status:

This is a draft proposed deliverable for review at the EHR Content TAG meeting on 11 March 2008. It is expected that this document will be replaced by a final document following that meeting. Therefore this draft document should not be regarded as current beyond the end of March 2008.

The document is derived from the incomplete draft Requirements document released to the TAG in November 2007 and relevant sections from the draft document on Approaches (December 2007) and Representation (January 2008).

Contents

1 Introduction

1.1 About this document

The first part of this document describes the requirements for linking elements of the SNOMED Clinical Terms® with information models. This linkage, referred to as *terminology binding,* is essential to minimise ambiguity and thus to maximise the reusability of clinical data and information captured, communicated and interpreted within the National Health Service (NHS).

The second part of the document explains principles that form the foundation for a coherent approach to *terminology binding*. This part summarises the relative strengths of structure and terminology in respect of representing particular aspects of meaning. It also includes a categorisation of different structural and semantic units and different types of *terminology binding*. Finally, it summarises and references other relevant material and notes some issues and outstanding challenges.

1.2 Other documents

This document acts as a foundation and point of reference for two other documents related to consistent application of *terminology binding*:

- A guide on how to apply *terminology binding* to specific business requirements and clinical information models.
- A technical document including:
    - A specification of form of machine readable representation of *terminology bindings*.
    - Functional requirements for tools to support the creation and maintenance of *terminology bindings*.

Note: These documents exist only in outline at this stage.

2 Glossary

2.1 What is terminology binding?

***Terminology binding** (noun)*: **an instance of a link between a *terminology component* and an *information model artefact*.**

Examples:

- A set of coded values that may be applied to a particular attribute in an information model. The set may be expressed either explicitly (extensionally) or as a definitional constraint (intensionally).
- The association between a named attribute value in the information model and a specific coded value or expression.
- A rule that determines the way that a coded expression is constructed based on multiple attribute values in the information model.

***Terminology binding** (verb)*: **the process or action of making one or more *terminology bindings*.**

> **Note: Do <u>not</u> shorten *'Terminology binding'* to 'term binding'**
>
> The abbreviation 'term binding' is deprecated because it is misleading. The target of *terminology binding* should never be a term.
>
> In the case of SNOMED CT, the *terminology component* that is the target of a binding is an *expression* or a set of *expressions*. Each *expression* refers to one or more identified SNOMED CT concepts.
>
> *Terminology binding* is principally concerned with what can be said - not how it is said. To specify a user-interface display or selection, a SNOMED CT description (or set of descriptions) may be specified in a binding. Even in these cases, the ultimate binding target is a concept-based expression, because a SNOMED CT description is a permanent binding between a *term* and a *concept*. On the other hand, a *term* may be associated with two or more *concepts* and must never be a binding target.

The following definitions apply to the definition and discussion of terminology binding.

***Terminology component*: a code value from a code system or a representation of a set of codes or a post-coordinated expression or a set of post-coordinated expressions.**

Examples:

- A SNOMED CT concept identifier, expression, reference set or constraint.

***Information model*: a formal description of how information may be structured, interrelated and accessed.**

Examples:

- The static HL7 model such as the Reference Information Model (RIM) or a constrained model or template derived from the RIM.
- An openEHR archetype or template.

***Information model artefact*[1]*:* an attribute, class or collection of related attributes and/or classes in an information model.**

Examples:

[1] A possible synonym for 'information model artefact' is 'information model fragment'.

- A coded attribute in an HL7 constrained model or template.
- A node or collection of nodes in an openEHR archetype or template.

3 Requirements

3.1 Why is terminology binding needed?

The primary requirements for *terminology binding* are to:

1. Constrain what can be expressed using a particular information model artefact.
    - To ensure that particular types of information are stored in appropriate information model artefacts;
    - To validate completeness against information content standards.
2. Provide picking lists bound to appropriate terminology concepts and/or constrained searches of the terminology.
    - To facilitate capture of coded structured information.
3. Enable the combination of an information model with a terminology to represent the meaning of clinical record entries in a consistent, unambiguous way. The variety and detail of meaning required may depend on a particular use case. However, within the limits of detail expressed, the resultant representations should enable consistent retrieval and processing.
    - To support effective reuse and sharing of structured coded information.

An effective approach to *terminology binding* must address all these requirements. Constraining what can or must be expressed enables more complete and comparable capture of specific clinical data sets. Picking lists and search constraints enhance the user interface and increase the ease of data capture. However, these relatively simple bindings are of limited value on their own because they do not address requirements for reuse and communication. Approaches to *terminology binding* that support consistent retrieval and reuse are more demanding but are a prerequisite for realising the potential value of electronic health records.

3.2 Overview

The NHS Connecting for Health web site summarises its role as supporting "… the NHS to deliver better, safer care to patients, via new computer systems and services, that link GPs and community services to hospitals". A key part of this is the "NHS Care Records Service (NHS CRS), an electronic records service which will mean healthcare staff will have better access to reliable patient and client information. The systems will support the delivery of better safer health care".

To achieve this objective, clinical information from different sources must be represented in forms that meet a variety of practical requirements. Efficient and safe delivery of clinical services requires appropriate reuse of information. Therefore, it is important to visualise specific uses of clinical information as part of an overall life-cycle. This life-cycle starts with data capture and storage. It continues through retrieval which enables reuse for display, decision support, analysis and communication (see 4.1).

Different stages in the clinical information life-cycle are characterised by different requirements. Similarly, specific functional requirements arise from analysis of particular clinical domains, and particular stages in the business process. Analysis of differing requirements often leads to different ways of representing similar information (*representational forms*). A particular *representational form* may suit a given set of requirements by exposing, clarifying and optimising access to relevant facets of the information (see 4.2.1).

The diversity of *representational forms* arising from analysis of specific requirements poses a challenge for effective reusability. If clinical information is to be reused, it must be possible to transform data collected in one form into a form that is appropriate for another use. Furthermore, these transformations must be performed without loss of relevant information. The task of creating and maintaining many use case specific transformations is unsustainable. A shared model of the underlying meaning of items of clinical information is needed as a common point of reference to facilitate consistent transformations. The shared *model of meaning* should encompass the different *representational forms* that may be applied to similar types of clinical information. This shared understanding does not require that all *representational forms* are equally detailed. Furthermore, the shared model need not support every facet of local system functionality. The important point is that the shared model should support transformation without loss of details that are relevant to the purposes for which the information is being reused (see 4.2.2)

Any reuse of information requires some form of selective retrieval. Therefore, the ability to generate representations that meet a variety of selective retrieval requirements is the primary determiner for shared model of meaning (see 4.3).

A *representational form* consists of several distinguishable parts. Two of these parts are the structures used to organise the data (*information models*) and the codes used to express clinical concepts in a processable manner (*terminologies*)[2]. Both these components contribute to the representation of processable meaning; some aspects of meaning are most effectively represented by structure and others by terminology. It is useful to understand their relative strengths and weaknesses in order to manage overlaps and potential conflicts between alternative representations (see 5).

The NHS is using a variety of different standards and specifications to address particular aspects of its requirements for representation and management of clinical information. Some of these relate to *information models* or *terminologies* and thus fall within the scope of *terminology binding*.

Two standards for structuring clinical information have been used by NHS CFH. The NHS CFH Message Implementation Manual (MIM) specifies messages based on the HL7 Version 3 Reference Information Model (RIM). Current NHS CFH work on data content requirements uses *open*EHR templates and archetypes derived from the CEN Standard on 'Electronic Health Record Communication' (EN13606) (see 8.1).

[2] Other aspects of a *representational form*, while relevant to interpretation of a record, are outside the scope of *terminology binding*. These include references to named or identified real world entities (e.g. people, places, organisation), dates and times, numeric values and quantities and artefacts that support record management (e.g. authentication, attribution, access control, audit trail).

Although two distinct standards form the basis for NHS CFH *information model* developments, other *information models* also need to be considered. There are two reasons for this. Firstly, the NHS CFH work has extended, refined and interpreted some aspects of these underlying standards to meet specific use cases[3]. Secondly, clinical applications procured for use within the NHS have their own internal information models. One result of this diversity is the need to consider how a standardised representation of *terminology binding* will be implemented. While the primary focus of this document is current work with *open*EHR, its recommendations are influenced by and relevant to work with other *information models* (8.3).

The principle *terminology* for representation of clinical information in the NHS is SNOMED Clinical Terms® (SNOMED CT) [4] and this terminology is the focus of this document[5]. Aspects of meaning implicit in a specific structural element of one *information model* need to be made explicit so they can be transformed to a representation supported by another *information model*. Where possible, the recommended approach uses the features of SNOMED CT to make the meaning explicit and thus bridge the gap between different *representational forms*. There are limitations to this approach; areas of weakness and incompleteness in SNOMED CT and limited implementation of particular SNOMED CT features by existing applications. However, the expressivity of SNOMED CT already covers many key gaps between different information models and within the NHS CFH strategy it represents a single point of reference (see 9).

The relationship between an *information model* and a *terminology* has a profound effect on the ability to represent particular items of information in a consistent and reusable manner. The objective of *terminology binding* is to express these relationships in a clear and processable form. This requires an understanding of the different structural granularities of the information model and terminology (see 0).

Several different types of terminology binding are useful. These include constraints on use of terminology in particular nodes, fixed bindings between particular information model artefacts and terminology expressions, support for user-interface selection of appropriate concepts and bindings that construct post-coordinated expressions from the content of multiple information model nodes (see 7).

[3] In both cases these NHS developments are based on particular threads of development from the source standard. For HL7, threads such as Clinical Statement and Clinical Document Architecture have been used as a foundation for specific NHS clinical communications. In the case of EN13606, the direction taken by *open*EHR has been followed to enable use of available tooling for archetype and template editing.

[4] The reference to SNOMED CT here should be regarded as including the NHS Dictionary of Medicines and Devices (DM+D) and other content in the NHS Extension of SNOMED CT.

[5] Similar *terminology binding* issues apply to legacy coding systems in use in the NHS (e.g. the Read Codes and NHS Clinical Terms), classifications used in the NHS (e.g. ICD10 and OPCS4) and code lists in the NHS Data Dictionary. In general, the limited expressivity of the source code systems reduces the range of options. Issues specific to these other code systems are outside the scope of this document. However, it is important to avoid any situation in which there is a code from another scheme has an implicit impact on the meaning of SNOMED CT expression. To avoid misinterpretation, these situations must either be avoided in design of the information model or explicitly represent in the *terminology binding*.

3.3 High-level statements

To address the requirements for *terminology binding* and to increase awareness of the issues, this topic was discussed on several occasions by the NHS EHR Technical Advisory Group[6]. In the course of those discussions the following statements on *terminology binding* were agreed:

1. The requirements for terminology-binding to information models should be driven by data retrieval requirements.
2. Data retrieval requirements should guide data capture specifications.
3. The SNOMED CT concept model should be exploited to the full in NHS data retrieval specifications:
    - Where the SNOMED CT concept model does not meet requirements, efforts should be made to enhance the concept model to meet requirements in future.
    - This does not preclude applying constraints on the use of the SNOMED CT concept model.
4. Some overlaps between information models and terminology models may be deemed useful or necessary in a 'grey zone' where the merits of alternative representations are finely balanced or use case specific. Coded information items within these overlaps should be defined in such a way that fully automated and loss-less transformation is possible between permitted alternative representations.[7]
    - This means that the principles for *terminology binding* (including using the SNOMED CT concept model as a conceptual framework) should influence the design of 'grey zone' data specifications within the information models.
5. Detailed terminology-binding rules should be fully illustrated with implementation examples.

These statements are based on and explained further by the content of this document.

[6] These statements were accepted as formal recommendations by the NHS EHR Technical Advisory Group at the TAG meeting on 11th December 2007.

[7] Note: Statement 4 has been revised since the agreed version in an attempt to clarify it. The original agreed text was as follows:

"Where overlap areas are deemed useful or necessary between information models and terminology models (i.e. within a 'grey zone'), coded information items within this overlap should be defined in such a way that fully automated and loss-less transformation is possible between the two.

- This may mean that the principles for terminology-binding (including using the SCT concept model as a conceptual framework) will influence the design of 'grey zone' data specifications within the information models."

4 Clinical information life-cycle and representational forms

4.1 Clinical information life-cycle

4.1.1 The significance of the clinical information life-cycle

Terminology bindings specify how the combination of an *information model* and a *terminology* are used to represent items of clinical information. It is possible to view clinical information representation from several different perspectives and these may influence decisions on the types of bindings that are required.

If information is to be reusable, the full life-cycle of the information must be considered. Ideally there should be an end-to-end specification covering all essential functionality.

> For example, it is not sufficient to think of *terminology binding* simply in term of the way that terms are selected for data entry, since the same information will need to be stored and displayed. It may also need to be used for reporting and analysis or communicated to another system.

A simple overview of the stages in this life-cycle is shown in Figure 1. In general, information from data capture or inbound communications is stored and then used for other purposes including display, decision support, reporting & analysis and outgoing communications.

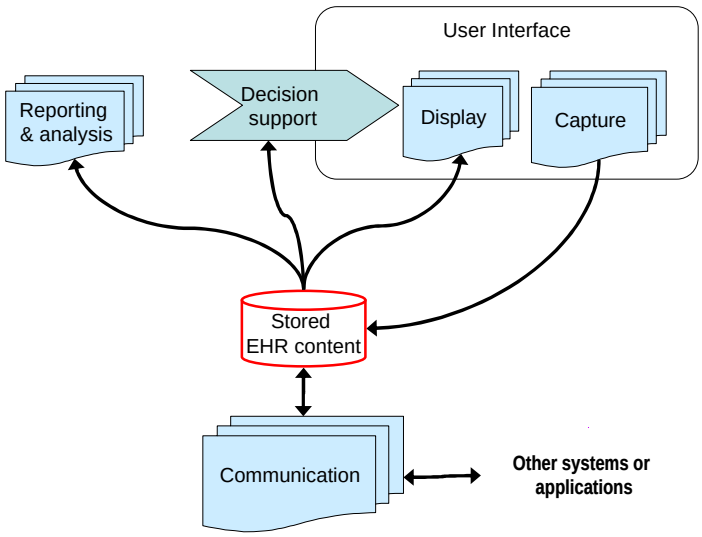


Figure 1. A simple view of the clinical information life-cycle

There are some apparent exceptions to the simple steps shown in Figure 1. However, it is a useful overall generalisation in which to locate key stages that influence the way that *terminology binding* is perceived. To illustrate this point the following notes indicate how some exceptions can be accommodated in the general diagram.

Examples of possible exceptions from Figure 1

a) Captured data may be communicated without being stored locally

- This is a variant of the 'capture'→'stored EHR content' step with the communication being integral to process of storage[8].

b) Inbound communications may be viewed without being stored locally

- This is a variant of the 'stored EHR content'→'display' step with the communication being integral to process of display.

c) Data may be captured by automatic monitoring equipment rather than a traditional user interface.

- This can either be regarded as inbound 'communication' from the system or application capturing the data or as an extension of the user-interface.

A further elaboration of the steps shown in Figure 1 is illustrated by Figure 2.The addition of general 'Retrieval' step in this diagram emphasises that any reuse of stored 'EHR content' requires some type of retrieval.

The nature of the retrieval requirements varies but the key to effective reuse is the ability to selectively retrieve and process captured or communicated information. A hallmark of effective *terminology binding* is the extent to which it enables consistent retrieval based on processable meaning in the EHR content.

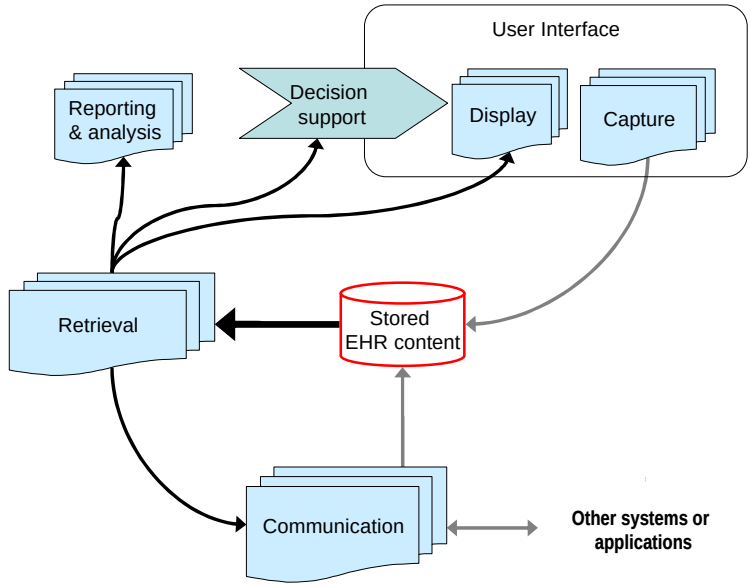


Figure 2. A generalised view of the clinical information life-cycle

[8] Asserting that this communication is integral to data capture and storage implies that it can be treated in the same way as local data capture. Thus this type of communication does not alter the *terminology binding* requirements.

4.1.2 Life cycle views of terminology binding and data requirements

4.1.2.1 General views of data requirements

Business and clinical requirements frequently refer to a 'required data set' or 'data requirements'. Some of these statements of requirements may be specific to a particular point in the information life-cycle (e.g. a business requirement for communication of a given set of information) while others may seem more general.

Often more detailed analysis reveals that specifications that are explicitly related to a specific stage of the life-cycle make assumptions about other stages.

> For example, a communication specification may require recent capture of some of the items to be communicated (e.g. current blood pressure) and may make different unstated assumptions about others (e.g. a requirement to communicate 'family history' may not require an existing record to be refreshed or reconfirmed).

Conversely, some specifications described as 'data requirements' may be requirements for data capture or requirements for information to be available and retrievable. Table 1 illustrates this point with some of the many possible implications of a data requirement for 'past history of ischaemic heart disease'.

Table 1. Possible meaning of a 'data requirement' for 'past history of ischaemic heart disease

a) Capture:
   i. Display a prompt and require (or allow) the clinician to mark answer 'yes', 'no' (or possibly a null flavour such as 'not known', 'not asked', etc); or
   ii. Display a prompt and allow the clinician to search for and select one or more types of ischaemic heart disease to be recorded in the patient's past history.

b) Retrieval:
   i. Check if the patient has a specific record noting a 'past history of ischemic heart disease' is present.
   ii. Check if the patient has record of a past history of any subtype of 'ischaemic heart disease'.
   iii. Check if the patient has any record of diagnosis of ischaemic heart disease in their record at some time in the past.
   iv. Check if the patient has any record of diagnosis of ischaemic heart disease or a subtype of ischaemic heart disease in their record at some time in the past.
   v. Any or all of the above.

c) Display and reporting
   i. Depending on the results of (b) display the latest explicit status information indicating presence or absence of a past history of ischaemic heart disease.
   ii. Display or report the full details of the most recent record returned by (b).
   iii. Display or report information matching the criteria in (b).
   iv. Analyse the records returned by (b) for other relevant criteria.

d) Decision support
   i. Trigger rules or advice based on the raw results of (b).
   ii. Further process the specific records returned by (b) to determine the rules or advice to be triggered. For example, dates, certainty, author, specific nature of the condition etc.

e) Communication
   i. Communicate the presence or absence of ischaemic heart disease determined by (b).
   ii. Communicate the most recent record or all records retrieved by (b).

f) Mixed display and capture (also a type of decision support)
   i. Retrieve data as in (b) and use this to auto-populate or suggest a default response in a data capture screen.
   ii. Require the user to acknowledge that they have or have noted (and possibly reconfirmed) displayed information returned by (b).

4.1.3 Terminology binding for data content and retrieval requirements

A statement of 'data retrieval' requirements can be viewed as describing the questions (or types of question) that it should be possible to answer. The information to enable these questions may have been derived from one or more sessions of data capture. The information may have been captured directly or may have arrived by communication from another application where the data was originally captured. The test of whether a 'data requirement' has been met, is whether it is possible to answer relevant questions in a consistent and authoritative way.

There may need to be several ways to capture similar information, the retrieval representation allows questions about that information to be answer correctly irrespective of the way in which it was captured. This implies that *terminology binding* should be consistent across all data capture environments and throughout communications between different applications.

> In summary; **Data content requirements should facilitate consistent retrieval of information to meet a use case or set of use cases. Different approaches to data capture may meet the same retrieval requirements.**

4.1.4 Terminology binding for data capture requirements

A statement of 'data capture' requirements should be designed to serve the process of meeting 'data content requirements' in ways that:

> Make it very easy to enter information that is required or known to be frequently relevant.
>
> Make it possible to enter information that may be relevant
>
> Ensure that required information is entered.
>
> Ensure that information is recorded in ways that are clinically safe, logically valid and facilitate frequent processing.

Data capture requirements focus on ease of use in line with clinical practice, which varies between disciplines, specialties and the settings in which care is delivered. Therefore, similar information will frequently be captured in different ways and to different levels of detail. However, the resulting information should be transformable into common structures that allow consistent retrieval. Therefore, the ways in which terminology components are bound should be determined primarily by the data content and retrieval requirements rather than specific data capture requirements.

> In summary; **Data capture requirements should focus on assisting and validating data entry to meet a given use case.**

4.1.5 Terminology binding and communication

Communication specifications may be driven by specific business processes (e.g. requests and reports) or by more general requirements to share electronic records (e.g. GP to GP transfer and shared care). The requirements of specific business cases tend to be more focused and limited in much the same way as are many data capture scenarios. Record-sharing communications that seek to deliver semantic interoperability between independent applications have much in common with data content and retrieval requirements.

There are existing guidelines on binding SNOMED CT to some communication based models (i.e. in NHS CFH specifications and in the HL7 TermInfo Draft Standard for Trial Use "Guide to the use of SNOMED CT in HL7 Version 3"). While these do not cover all NHS CFH requirements, they do provide a point of reference. Therefore an important test of the *terminology binding* rules for openEHR archetypes and templates is whether the results of applying them can be reproducibly transformed to representations that comply with those guidelines.

> In summary; **Outbound communications require data to be selectively retrieved and transformed to align with agreed standards for messaging and data transfer. Inbound communications require data structured in accordance with agreed standards to be transformed for storage and reuse.**

4.2 Representational forms

4.2.1 Representational forms and the information life-cycle

The life-cycle illustrated in section 4.1 outlines the different stages through which clinical information may pass. Different requirements are associated with these stages and these requirements may result in differences in the forms associated with each stage.

> For example, the structure appropriate for message between applications is likely to differ from the structure used for storage and retrieval.

The *representational forms* used at each step in the life-cycle must be transformed to meet requirements of other steps. If these transformations are to be carried out without loss of information, there must be a clear relationship between the *terminology bindings* applied to each of these forms.

> For example, the way that SNOMED CT is bound to the archetypes and templates used to define data content requirements must be related to the way that SNOMED CT is bound to NHS CFH communication specifications used to communicate that information. To enable efficient, consistent and testable transformation of instance data these relationships must be machine processable and testable.

Therefore, it is useful to consider the nature of the different *representational forms* that meet these practical requirements and the use cases for transformations between them.

- Processes such as data capture, display, retrieval, analysis, communication and storage have distinct but interrelated representational requirements.
- Representational requirements also vary according to the specific practical, clinical and business aspects of these processes.

The idea of a *representational form* is broader than, though inclusive of, the models specified by various standards. *Representational forms* include:

- Human-readable renderings for data capture and display
- Communication specifications and implementation guidelines
- Report specifications and requirements for aggregation and analysis
- Decision support specifications that require records to be checked for particular information
- Schemas used for physical storage[9].
- Virtual views[10] of stored information that enable selective retrieval of information for display, communication, reporting and decision support.

[9] Storage representations need to optimise all aspects of data processing (including capture, retrieval and communication) while also maintaining an authenticated audit trail. Security and authentication issues are outside the scope of this paper and optimisation is generally regarded as proprietary design and development issue.

[10] A *virtual view* is either explicit or implicit in non-proprietary requirements for consistent selective retrieval from a proprietary storage structure. An explicitly defined *virtual view* that is shared by a range of different retrieval specifications is a prerequisite for efficient reuse.

Table 2 summarises the kinds of *representational forms* required to support an effective clinical information system. Figure 3 illustrates the relationships between these different representations.

Table 2. Summary of representational forms

Requirement	Examples
User interface representations (human-readable)	
Data capture representations - relevant to particular business purposes, disciplines, specialties and situations.	Screen layouts and user-interface features used to facilitate the consistent recording of information.
Data display/report representations – relevant to particular business purposes, disciplines, specialties and situations.	Screen or report layouts used to review information as part of information gathering.
Statutory and legal representations	To provide information in authenticated auditable forms acceptable for statutory and legal purposes.
Communication representations (machine-processable – may include human-readable sections)	
Representations for communications that fulfil specific business purposes	Requesting or reporting on a service.
Representations for communication of extracts of a clinical record	GP to GP communications, communication between local clinical systems and the NCRS, support of shared care between users at a local level.
Representations suitable as archival, backup and transfer forms	To support disaster recovery, migration between systems or roll-back after data conversion.
Retrieval based representations (machine-processable views[11])	
Representations that support a range of retrieval requirements in relation to individual patients.	To enable real-time decision support.
Representations that support a range of retrieval requirements related to populations	To enable epidemiology, research, clinical audit, batch-mode decision support[12].
Representations that support generation of selective views of the patient record (see also Data display representations)	To display all known allergies, adverse reactions, current medications, vaccinations, immunisations status, current problems/issues, quantitative observation trends.
Storage representations (machine-processable)	
Representations in which clinical information is stored for use for the purposes identified above	Proprietary storage schemas, NRCS and Secondary-uses repository schemas.

[11] In practice, these representations may be 'virtual views' applied to a 'storage representation' (i.e. the system responds to queries as though a retrieval-based representation existed).

[12] 'Batch-mode decision support' involves analysing records of a population of patients for particular markers that may indicate a need for recall for review of adjustment of treatment regime. This is clinically relevant where a treatment regime changes based on research, evidence or published guidelines. A routine recall system for immunisations or other preventive action can be regarded as a simple case or 'batch-mode decision support'.

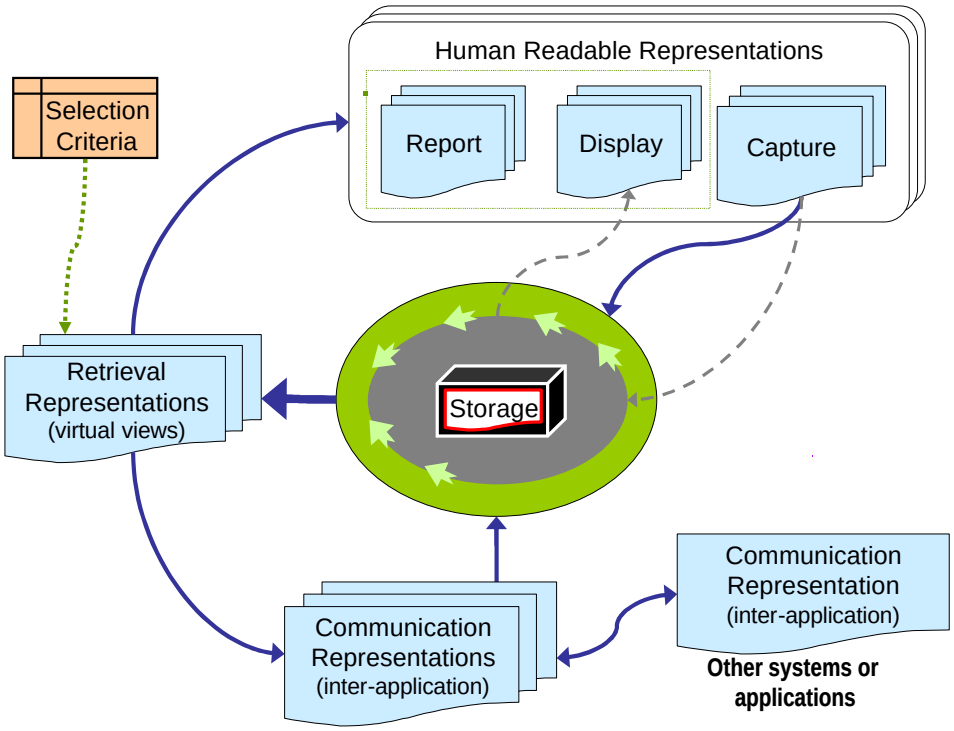
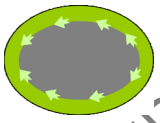


Figure 3. Diagrammatic summary of the relationships between representational forms

Key to diagram

	The set of *representational forms* of a particular type. These are assumed to be representations based on NHS CFH specifications (where they exist) but they may also be augmented by proprietary representations that fall outside the scope of current NHS CFH specification.
	The green area represents requirements for demonstrable (system independent) loss-less transformation between instances based on different NHS CFH specifications. The green arrows represent the rules for these transformations, flowing from data capture and inbound communications to various forms of retrieval. The grey area represents the application area in which transformations occur between instances based on NHS CFH specification and proprietary storage forms. The intention is that net result of these transforms should be equivalent to those represented by the green arrows.
	The proprietary internal storage and functionality of a system comprising one or more tightly coupled applications. This is shown as a 'black-box' containing a storage representation. The storage representation may be proprietary but the stored information must be transformable to and from other *representational forms*.
	The flow or transformation of information between *representational forms*. The broken line shows examples of proprietary information flows that may bypass transformation and augment the specified common flows.

4.2.2 Transformations between representational forms

Table 3 summarises the relationships between *representational forms* used at different stages in the life-cycle – as illustrated in Figure 3.

To meet end-to-end processing requirements it must be possible to

- Derive each form from its source form(s).
- Use each form to generate its associated target form(s).

Table 3. Relationships between representational forms

Representations	Relationships
Human-readable representations	
Data capture Representations	*Source:* Application user. Typically supplemented by data display representations as context for data capture.
	Target: Storage representations and (indirectly) retrieval, human-readable and outbound communication representations.
Data display Representations	*Source:* Storage or retrieval representations and (indirectly)
	Target: Application user.
Report Representations	*Source:* Retrieval representations
	Target: Data display, printed reports and aggregated data analysis
Machine-readable representations	
Communication Representations	*Source (outbound communications):* Storage or retrieval representations.
	Target (inbound communications): Storage representations and (indirectly) retrieval and human readable representations.
Retrieval Representations	*Source:* Storage representations and (indirectly) data capture and inbound communication representations.
	Target: Human-readable and outbound communication representations
Storage Representations	*Source:* Data capture and inbound communication representations
	Target: Retrieval representations and (indirectly) human-readable and outbound communication representations.

No single *representational form* meets all requirements therefore these requirements must be met by transforming data from one form to another. Although each *representational form* may be specified to meet specific requirements it is also important to consider the general requirements to support these transformations. If data that is essential in a target form is unavailable or ambiguous in the source form, the transformation process cannot be completed reliably.

In practice, there are many different use case specific variants of each of the type of representations in Table 3. As a result, there is a requirement for a very large number of different transformations. The task of creating and maintaining many use case specific transformations is clearly unsustainable. The use of standards-based *information models* and *terminology* reduces the scale of this problem. However, unless the approach to *terminology binding* is consistent across all *representations forms* information will still be lost in the resulting transformations.

A shared model of the underlying meaning of items of clinical information is needed as a common point of reference to enable the necessary transformations between different *representational forms*. This shared model needs to encompass information models, terminology and the bindings between them. This does not require that all *representational forms* are equally detailed. Furthermore, the shared model need not support every facet of local system functionality. The important point is that the shared model should support transformation without loss of details that are relevant to the purposes for which the information is being reused.

A practical first step toward a shared model is to ensure the way that *terminology binding* is applied to *open*EHR archetypes and templates is consistent with other NHS specifications. In particular, it should be possible to derive HL7 Clinical Statement compliant representations that are aligned with templates used in the NHS MIM[13]. This requirement influences the nature of terminology bindings required.

Example – Symptom

A concept such as 'pain the left thigh' could be conveyed as a single HL7 clinical statement containing a post-coordinated SNOMED CT expression.

The simplest 'close to user' representation of this would be[14]:

78514002 | thigh pain | : 272741003 | laterality | = 7771000 | left |

The *open*EHR archetype for symptoms (see Appendix B:) has nodes that support a multitude of different features; some of which are well modelled in SNOMED CT, some can be represented by separate pre-coordinated finding concepts while a few cannot be readily represented using SNOMED CT.

One of the feature nodes is 'Location in body'. This means two alternative representations need to be considered.

- The coded symptom node could be populated with the SNOMED CT expression above; or
- The laterality could be expressed in the 'Location in body' node.

Another option is to use the general concept for pain and specify the site and laterality in the 'Location in body'. This could be resolved to the following valid post-coordinated SNOMED CT expression.

22253000 | pain | : 363698007 | finding site | =
(68367000 | thigh structure | : 272741003 | laterality | = 7771000 | left |)

[13] This reference to HL7 Clinical Statement is inclusive of Clinical Document Architecture Release 2 (which is build of Clinical Statements). The resulting HL7 instances should also be compliant with the HL7 DSTU "Guide to the use of SNOMED Clinical Terms® in HL7 Version 3" with exceptions based on current NHS CFH conventions (e.g. NHS CFH uses *observation.code* rather than the recommended attribute *observation.value* for SNOMED CT clinical finding concepts).

[14] The examples SNOMED CT expressions are shown using the SNOMED CT compositional grammar. However, in current HL7v3 messages these expressions would be represented using the CD data type. The compositional grammar is shown here because it is clearer and shorted though logically identical.

The same approach can be followed for severity and onset which also have separate nodes in the *open*EHR archetype. However, it is not entirely obvious if 'current intensity' (in *open*EHR) is correctly interpreted as severity.

22253000 | pain | : 246112005 | severity | = 255604002 | mild |
,263502005 | clinical course | = 61751001 | gradual onset |
363698007 | finding site | = (68367000 | thigh structure | : 272741003 | laterality | =
7771000 | left |)

Example - Procedure

A concept such as 'reduction and internal fixation of fracture of the left femur' would be conveyed as a single HL7 clinical statement containing a post-coordinated SNOMED CT expression.

The simplest 'close to user' representation of this would be[15]:

86975004 | internal fixation of femur |:272741003 | laterality | = 7771000 | left |

The *open*EHR model seems to have a significantly different level of detail. It can clearly be used to construct detailed operative notes (e.g. archetype 'openEHR-EHR-ACTION.caesarian_section.v4draft'). However, the facilities for recording a procedure in a summary using (e.g. archetype 'openEHR-EHR-ITEM_TREE.procedure.v1') do not include a specific node for location or laterality. Therefore it would seem that the only viable option for expressing the procedure in a summary is to bind the post-coordinated expression in the procedure note. This is not a problem, in fact it simplifies matters by removing alternative options for representation. However, it does differ from the case for symptoms (see previous example).

Several semantically equivalent SNOMED CT expressions exist and would be permitted in the HL7 message. For example, the following expression uses a more general procedure and explicitly refers to the procedure site.

239293007 | internal fixation of fracture | :405813007 | procedure site - Direct | =
(71341001 | bone structure of femur | : 272741003 | laterality | = 7771000 | left |)

The most complete form (excluding context) is shown below.

71388002 | procedure | : {260686004 | method | = 129371009 | fixation - action |
,363700003 | direct morphology | = 72704001 | fracture |
,405813007 | procedure site - Direct | = (71341001 | bone structure of femur | :
272741003 | laterality | = 7771000 | left |)
,424226004 | using device | = 31031000 | orthopedic internal fixation system |

The significance of this fuller form is that it enables other refinements. For example the 'using device' attribute could be refined to [424226004 | using device | = 63289001 | metal nail].

[15] The examples SNOMED CT expression are shown using the SNOMED CT compositional grammar. However, in current HL7v3 messages these expressions would be represented using the CD data type. The compositional grammar is shown here because it is clearer and shorter though logically identical.

4.3 Retrieval requirements

4.3.1 Retrieval requirements as the driver for terminology binding

Section 4.2 describes how requirements associated with different stages in the life-cycle of clinical information result in the same information being represented in different ways. It also points out that *terminology binding* needs to support loss-less transformation between these different *representational forms*.

Analysis suggests that the primary driver for *terminology binding* should be support for data retrieval requirements. The rationale for this assertion is that retrieval is required for all types of information reuse (display, reporting & analysis, decision support and communication). Thus the value of capturing and storing information depends on effective support for retrieval.

4.3.2 Types of retrieval requirements

Several different types of retrieval requirements need to be considered (see Table 4).

The simplest requirements for retrieval can be met without a controlled terminology and can be ignored when considering *terminology binding*.

On the other hand, effective *content-based selective retrieval* requires consistent computer processable representation of the meaning of clinical content. A controlled terminology with rich semantics (such as SNOMED CT) is one of the tools required to meet these requirements. However, the ability to make full use of the terminology must be assisted rather than impeded by the way it is bound to and used in an information model.

> For example, consider a retrieval request to determine if the patient has a family history of asthma.
>
> - If the information model offers several distinct structures with which to represent family history information all these will need to be explored.
> - If *terminology binding* is too loose, it may allow SNOMED CT concepts that represent disorders to be used in ways that do not clearly indicate whether these are family history or conditions present in the patient.
> - It *terminology binding* is too constrained it may not permit some disorders to be recorded in the family history.

The acid test for any approach to *terminology binding* is the extent to which is supports consistent *content-based selective retrieval*.

Table 4. Types of retrieval requirements

Retrieval requirement	Examples
Simple retrieval	
Selection of a note or document based on selection criteria such as patient, author, clinical service type or location, dates.	Simple redisplay of notes or documents during a clinical encounter. Legal and audit requirements for record retention and manual review.
Content-based selective retrieval	
Selective retrieval from the record of a patient using content-based criteria. Content-based criteria include: • Presence or absence of clinical content (e.g. problems, disorders, allergies, history, risks, symptoms, signs, investigation results, medication, procedures including surgery and other therapies). • Associations between clinical content items (e.g. asserted associations such as causality and temporal relationships such as co-occurrence).	Displaying and highlighting specific information derived from one or more notes about a patient (e.g. allergies, significant past, family history, etc).
	Enabling decision support tools to determine the presence or absence of significant factors in a patient record.
	Including clinical information in a message or other communication (e.g. transferring a summary or a record extract, including relevant information with a request, referral or specialist report).
Selective retrieval from records of members of a population using content-based criteria. Content based criteria of the types noted above may be used to select a sub-population. Similar criteria may be applied to analyse a population or to compare different selected sub-populations.	Clinical uses identifying patients who may benefit from follow up, review, specific investigations, preventative care or changes in treatment.
	Research uses such as analysis of outcomes for particular conditions and also to identify patients for trial and control groups in prospective trials.
	Epidemiology uses such as detection and analysis of epidemics and other population wide health factors.
	Management uses such as clinical audit and service planning and risk monitoring.
	Educational use such as providing access to representative case studies.

4.3.3 Retrieval requirements and data capture preferences

A retrieval driven statement of 'data content' requirements can be expressed as the set of questions (or types of question) that it should be possible to answer.

The test of whether a 'data content' requirement has been met is whether it is possible to answer relevant questions:

- Consistently – as far as possible independent of source of data;
- Completely – no false negatives;
- Precisely – no false positives;
- Efficiently in terms of:
    - Usability – ease of expressing retrieval requirements in a processable form;
    - Performance – timely responses (e.g. real-time for decision support).

The possibilities for retrieval are limited by the amount and detail of information captured and by the extent to which this is represented in a processable form. Different representational forms can enable adequate retrieval for a specific purpose. However, to meet the overall requirements for the EHR it should be possible to pose questions in common forms – thus, while the results may be dependent on whether data was captured, they should not depend on how the data was captured.

The information required to answer these questions may be derived:

- From one or more clinical encounters during which different data capture tools are used to meet the requirements of particular environments.
- By communication from another application where the data was first captured.

These different sources of data capture should not impact on the ability to retrieve it (see example in Figure 4). This does not require the forms in which information are captured, stored or communicated to be identical. However, information from various sources does need to be transformed into a common view that responds consistently when interrogated by clinical queries. This implies that *terminology binding* should be consistent across all data capture environments and throughout communications between different applications.

The question **'has the patient had a rash in the last ten days?'** should be answered in the affirmative, independently of the way in which the rash was reported and recorded.

For example it might have been captured …

- As a record of an adverse reaction to immunisation.
- As a record of an adverse reaction to a drug.
- As a symptom or complaint reported by the patient in a general encounter
- As a finding recorded during examination.
- By the patient clicking a check box on a pre-immunisation review form.
- Communicated from an immunisation clinic to a GP system.

Note

Some questions may also be concerned with provenance of the information (i.e. who reported the rash). However, for the purpose of this example the assumed requirement is to identify any report of a rash – not necessarily one specifically seen by a clinician or stated to be an adverse reaction.

Figure 4. Examples of alternative ways to capture similar information

5 Overlaps between information & terminology models

The semantics expressivity of the terminology model inevitably overlaps with the semantics of the information model. This creates alternative representations of similar meanings. In many cases, it is sensible to prefer one representation and deprecate or prohibit others. However, there are some cases in which alternative representations of similar information may be useful or unavoidable. These fall in a 'grey zone' where the relative merits of terminology and information models are finely balanced or are dependent on specific use cases. Coded information items that fall within these overlaps should be defined in such a way that fully automated and loss-less transformation is possible between the two.

Between any pairing of a structural information model and a terminology model, there are almost certain to be either gaps or overlaps. In some cases, there will be both gaps and overlaps.

A gap exists where the terminology does not provide a coded representation that the information model presumes can be coded in a particular way.

> For example, if an information model assumes that the terminology can distinguish between "fracture of the left tibia" and "fracture of the right tibia" but a chosen terminology does not support this.

An overlap exists where both information model and terminology model have ways of expressing a similar aspect of meaning.

> For example, where an information model structure exists for representing "family history" and specific codes or expressions in the terminology are able to represent family history.

Most gaps are likely to fall fairly clearly in either the terminology or structural model. There will be gaps in SNOMED CT content coverage and these will need to be managed through the NHS Terminology Service and IHTSDO request submission process. There may be gaps where archetypes need extending to include additional attributes for text, dates or numeric values.

There are many potential overlaps and these present significant challenges. The overall challenge is to ensure that this overlap does not result in loss of processable or human readable information. This may be achieved either by selecting a single approach to each type of overlap or by defining alternative approaches in such a way that fully automated and loss-less transformations are possible between alternative permitted representations.

5.1 Alternative approaches to resolving overlaps

The areas of overlap are illustrated with examples in Figure 5. The illustration divides to overlap into three parts representing different decisions that may be made about particular types of overlap.

Preference based resolutions

- Some types of overlaps are best managed by a terminology-led approach
- Some types of overlaps are best managed by a structure-led approach

These preferences depend on the relative strengths of the approaches and vary according to the type of overlap. Agreeing a preference may be necessary to avoid situations where loss-less transformation would otherwise be intractable or impossible.

Dual approach based resolutions

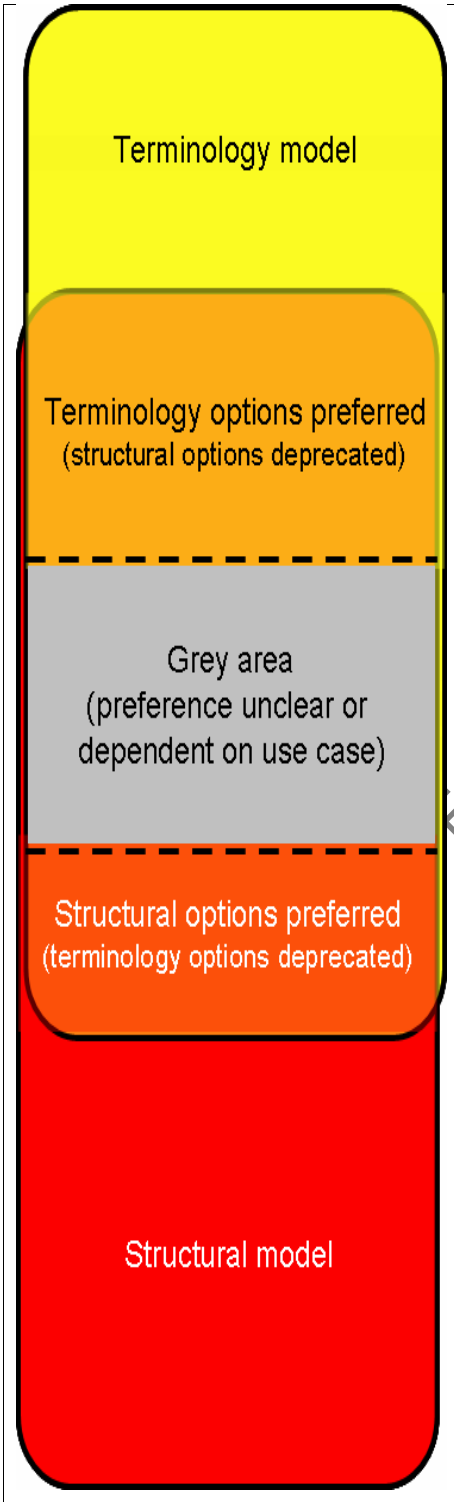
- Some types of overlap may be better managed by guidance that is specific to different use cases

If it is possible to perform tractable loss-less transformations, then it is feasible to permit alternative approaches. This is useful if the optimum approach is dependent on variable factors such as the level of detail that needs to be captured in particular situations.

Some organisational challenges arise from deprecating features of an approach that may be needed in other circumstances (e.g. when SNOMED CT is used with a different information model or when openEHR is used with a different terminology). In these cases, the advocates of each approach may be disinclined to support the necessary compromises. However, from the perspective of the NHS it is essential to ensure that there is an agreed approach which effectively balances and builds on the strengths of the different component standards.

Other approaches

A more complete range of options for dealing with gaps between an information model and a terminology model were explored during the HL7 TermInfo Project and are described in an appendix to the HL7 "Guide to use of SNOMED CT with HL7 Version 3". Table 5 shows the general options identified in that document (revised to generalise from HL7 to any information model).



Terminology model

Specific concepts:

For example, diseases, symptoms, signs, procedures, drugs, etc

Semantic relationships between concepts

For example, relationship between "viral pneumonia", "lung", "virus", "infectious disease".

Representation of constraints on use of terminology

For example, concept model and value-set definition formalism.

Terminology model preferred

Constraints on combination of concepts in instances including abstract model of post-coordination and permissible attributes and ranges for refinement of concepts in specified domains:

For example, restrictions on "finding site" refinement of "appendicitis", conventions on representation of laparoscopic variants of procedures.

Grey area

Representation of contextual information related to instances of clinical situations

For example, family history, presence/absence, certainty, goals, past/current, procedure done/not-done, etc.

Representation of additional constraints on post-coordination of concepts for specific use cases

For example, constraints on terminology use specific to immunisation and related adverse reaction reporting.

Structural model preferred

Representation of relationships between distinct instances of record entries and other classes

For example, grouping of record entries related by timing, problem or other organising principals.

Structural model

Attributes with specific data types

For example, dates, times, durations, quantities, text markup.

Identifiable instances of real-world entities

For example, people, organisations, places.

Overall record and/or communication architecture

For example, EHR extract, EHR composition, openEHR reference model, CDA documents, HL7 messages.

Representation of constraints on use of particular classes or attributes in given use cases

For example, formalism for templates applied to constrain openEHR archetypes or HL7 CDA documents.

Figure 5. Summary of terminology and information model coverage and overlaps

Table 5. General approach to options for dealing with overlaps

	TR *Terminology representation Required*	**TO(I)** *Terminology representation Option (and is Included)*	**TO(O)** *Terminology representation Option (but is Omitted)*	**TP** *Terminology representation Prohibited*
IR *Information model representation Required*	Generate, validate and combine dual representations	Generate HL7 representation (if not present) Validate and combine dual representations	No overlap	Manage unconditional prohibition of Terminology representation
IO(I) *Information model representation Optional (and is Included)*	Generate Terminology representation (if not present) Validate and combine dual representations	Validate and combine dual representations	No overlap	Manage conditional prohibition of Terminology representation
IO(O) *Information model representation Optional (but is Omitted)*	No overlap	No overlap	No information	No information
IP *Information model representation Prohibited*	Manage unconditional prohibition of HL7 attribute/structure	Manage conditional prohibition of HL7 attribute/structure	No information	No information

Note: This table is derived from an table contributed by the author of this report to the HL7 TermInfo project.

6 Structural and semantic units

6.1 Binding granularity and complexity

An important starting point for any type of *terminology binding* is to decide which types of *information model artefact* should be bound to which types of *terminology component*. The underlying issue is the appropriate levels of structural or expressive granularity at which it is rational, practical and useful to assert bindings.

There is a temptation to consider only the simplest case – a single field (or node) in a template and the corresponding code (or set of permitted codes) in the terminology that might be used to populate that field. In practice, this is a huge over-simplification which, if followed, would fail to deliver the potential combined benefits of structure plus terminology.

- Different structure and terminology combinations can represent the same meaning.
- The range of possible ways to express information with different levels of structural and terminological granularity is even greater if representation of similar (possible less precise) information is also considered.
- The most common retrieval requirements are to find similar information rather than precise matches.
- The same SNOMED CT expression in a different structural element may have a significantly different meaning.

SNOMED CT allows subsumption and other relationships between concepts to be used to determine similarity between different terminology expressions. However, this depends on consistent use of the terminology.

- Two requirements that relate to similar information may be met using different structures. In this case, the ability to determine equivalence and subsumption using SNOMED CT relationships may be significantly reduced (see Figure 6)
    - The likely result of this is to overlook statements that should be regarded as satisfying a retrieval requirement ('false negatives').
    - This issue can be addressed if the *terminology binding* encompasses the structural alternatives in a consistent way. This is not possible if the binding simple relates one node to one code.
- The same SNOMED CT expression used in different structures may mean different things as a result of contextual information in the information model (see Figure 7).
    - The likely result of this is to incorrectly include statements that should not be regarded as satisfying a retrieval requirement ('false positives').
    - This issue can be addressed it the *terminology binding* allows information from different structural elements to be assembled into a post-coordinated SNOMED CT expression. Such an expression can explicitly represent the contextual inferred from the structure and supports more precise subsumption testing.

Therefore, consistent and effective reuse of information requires *terminology bindings* that can reference multiple nodes in the structural modes and sets of terminology components of varying levels of complexity. The tables in Section 6.5 and 6.6 provide more details on the ranges of *information model artefacts* and *terminology components* that may need to be bound to one another and the types of relationships between them.

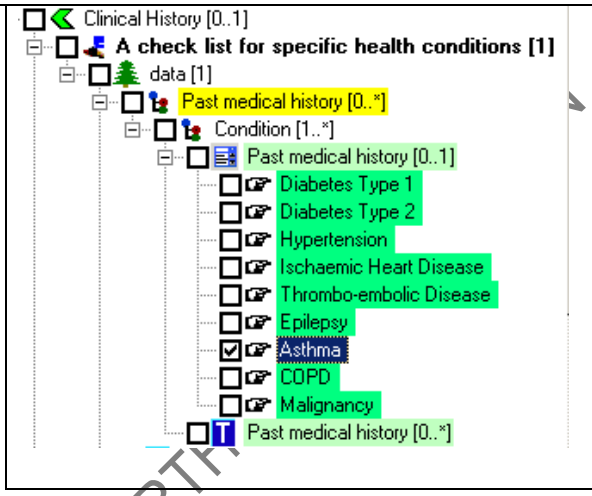
This archetype fragment allows past-history to be expressed.

One of the options that can be selected is asthma.

This node on its own would probably be coded as
[195967001 | asthma]

In the surrounding context would acquire the situation past history.
417662000 | past history of clinical finding | :
246090004 | associated finding | =
195967001 | asthma |

Or with the context expanded.



243796009 | situation with explicit context | :
{ 246090004 | associated finding | = 195967001 | asthma |
,408729009 | finding context | = 410515003 | known present |
,408731000 | temporal context | = 410513005 | past |
,408732007 | subject relationship context | = 410604004 | subject of record | }

The same archetype fragment includes a more general option to express any type of 'Past medical history' (using the node at the bottom of the illustration above). Logically there is no reason why this could not be coded with [195967001 | asthma] or with a more specific expression such as [389145006 | allergic asthma]. Either of these representations should return true to the question of 'does the patient have a past history of asthma?'

Another archetype used in the same template allows a diagnosis to be specified. Clearly 'asthma' is a possible diagnosis.

At the time of the record the 'diagnosis' imposes a specific temporal context (i.e. this is current condition).

However, implicitly following this diagnosis the patient has a 'past history of asthma'. Therefore, this is another representation should be retrieved by the question 'does the patient have a past history of asthma?'

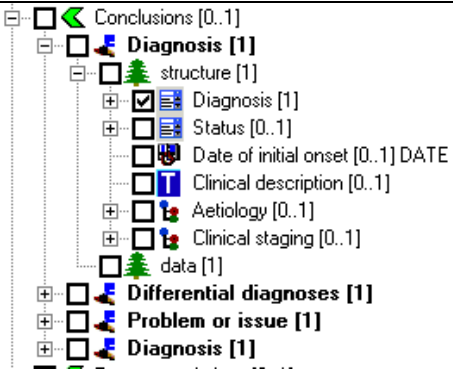


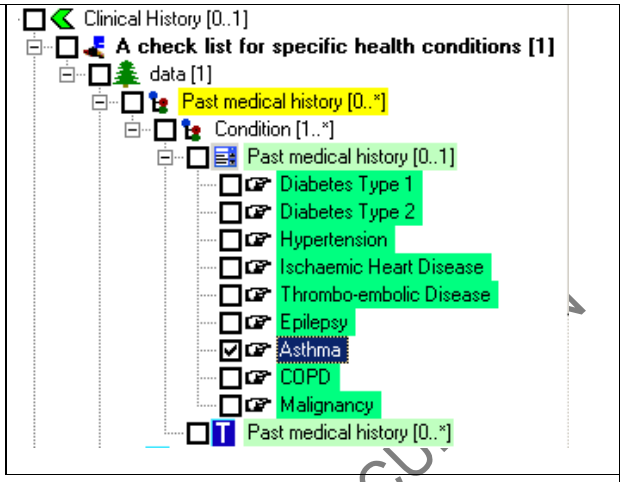
Figure 6. Similar information represented in different structures

This archetype fragment repeats the first illustration in Figure 6 in which a past medical history of 'asthma' is recorded using a selection from a list of disorders.

This node on its own would probably be coded as
[195967001 | asthma]

In the surrounding context would acquire the situation past history.
417662000 | past history of clinical finding | :
246090004 | associated finding | =
195967001 | asthma |

Or with the context expanded.



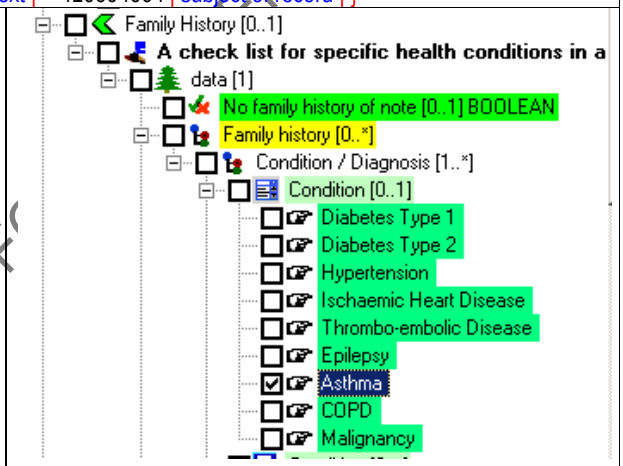
243796009 | situation with explicit context | :
{ 246090004 | associated finding | = 195967001 | asthma |
,408729009 | finding context | = 410515003 | known present |
,408731000 | temporal context | = 410513005 | past |
,408732007 | subject relationship context | = 410604004 | subject of record | }

This archetype fragment allows family-history to be expressed.

One of the options that can be selected is asthma.

This node on its own would probably be coded as
[195967001 | asthma]

However, in this case the surrounding context states this is family history.
281666001 | family history of disorder | :
246090004 | associated finding | =
195967001 | asthma |
Or with the context expanded.



243796009 | situation with explicit context | :
{ 246090004 | associated finding | = 195967001 | asthma |
,408729009 | finding context | = 410515003 | known present |
,408731000 | temporal context | = 410512000 | current or specified |
,408732007 | subject relationship context | = 303071001 | person in the family | }

Note

The structures used to represent past history and family history also have the facility to indicate negation (i.e. 'no past history of asthma' or 'no family history of asthma') or degrees of uncertainty. These meanings differ profoundly. For safe processing this information must not be lost in *terminology binding* or subsequent transformation.

Figure 7. Different information represented in similar ways

6.2 Describing structural and semantic units

In order to form a shared view that supports information reuse, we need a solution neutral way to talk about the units in a structure model to which a SNOMED CT expression may be usefully bound. Many of the potential words and phrases we might use are already laden with specific meanings related to a particular methodology. The following notes are an attempt to address this challenge in a way that enables a shared of different levels of semantic granularity which may be found in different models of electronic clinical records.

- An electronic clinical record can be considered to be divided into separate units of information (variously referred to as 'record entries' or 'clinical statements') which have an indivisible meaning that approximates to a single sentence[16] or utterance in human language.
    - To avoid confusion with existing names used in openEHR and HL7 these units of information are referred to in the following sections as 'hr-units' (health record units).
    - Similarly, the indivisible meaning that approximates to a single sentence or utterance is referred to the 'hru-clinical'.
- Each 'hr-unit' logically contains[17] references to particular people, dates, times and may also contain references to other 'hr-units'.
    - These references are <u>not</u> considered as part of the 'hru-clinical' but are essential to its interpretation.

      For example, each of the following quoted phrases expresses the 'hru-clinical', but to be interpreted each needs to refer to an identified subject and may also refer to related 'hr-units' (for example in the second case it may be related through the structural model to the associated diastolic blood pressure)

      "*[subject of record] has asthma*" -

      "[subject of record has] systolic blood pressure of 120 mmHg".
    - The representation of these references is determined by the structural information model.

[16] Where a sentence can be readily subdivided into two sentences without changing the meaning of the pair of sentences, then the unit is that subdivision. For example, "the patient has asthma and hayfever" can be restated as "the patient has asthma" and "the patient has hayfever" without loss of meaning.

Similarly, where the sentence includes detailed description of an entity this may be separated into a separate unit to fit the information model. For example, "intramuscular injection tetanus toxoid 0.5ml" can be divided into a unit that represents the action of inject and another that represents details of the substance administered.

[17] The phrase 'logically contains' is used to imply that it may either contain the specified information directly or by reference (for example the patient may be identified by a surrounding container rather than within the 'hr-unit').

- Each 'hr-unit' may contain a human-readable textual rendering of the 'hru-clinical'
    - This may be required for medico-legal reasons or to add detail to a coded representation. Otherwise, it is not essential for the 'hr-unit' to contain an explicit textual rendering, as this may be derived from other representations of the 'hru-clinical'.
- Each 'hr-unit' may contain a coded representation of the 'hru-clinical'.
    - This coded representation may:

      Completely encapsulate the 'hru-clinical'; or

      Provide a label for a value which, when populated with other data such as a numeric quantity or range, fully expresses the 'hru-clinical'

      Provide a less detailed representation that is expanded by text;
    - The extent of this coded representation is determined by the terminology model.
- Each 'hr-unit' may contain additional information to supplement the textual and/or coded representations. This information may include references to particular people, dates, times, quantities, images.

6.3 Structural options for representing terminology elements

The underlying 'hru-clinical' of each unit of information can be represented in various ways in a structure information model.

One approach is to support native SNOMED CT expressions directly in an information model structure.

For example, a post-coordinated expression could be used in the code value attribute of an HL7 Act (Figure 8) or a text element in an archetype (Figure 9).

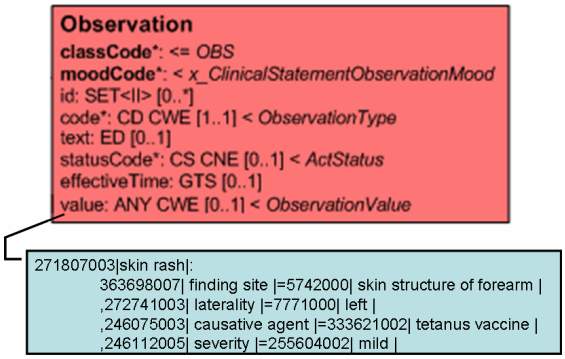


Figure 8. Using a SNOMED CT expression[18] to represent the finding directly in HL7v3

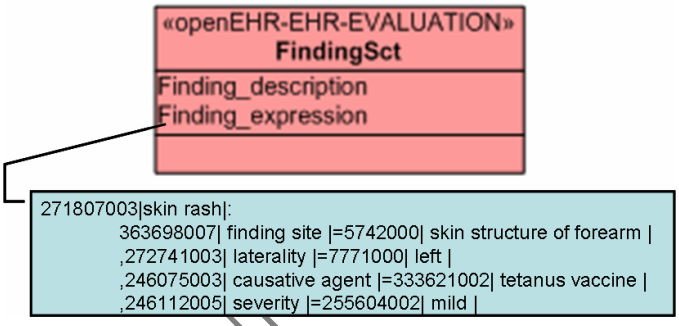


Figure 9. Using a SNOMED CT expression to represent the finding directly in an archetype

[18] In these examples, the full form of the text including identifiers and terms is used. The terms are optional and may be removed if they are not required for operational or medico-legal reason.

An alternative approach is to use multiple elements in the structural model to represent different facets of the coded 'hru-clinical'. This is compatible with a terminology view, provided that each element is explicitly bound to a specific concept model attribute.

For example, separate data points could be used for each of the required attributes as shown in Figure 10.

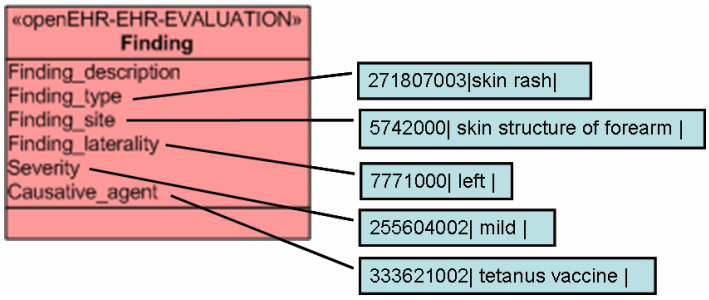


Figure 10. Using specific information structures and binding them to SNOMED CT semantics

In these simple examples, each of the approaches can represent the same information and can be readily transformed to one of the other forms. In all cases, the instance data is represented in a flat 'close-to-user' form which can be converted to a normal form using the transformation rules specified by SNOMED CT.

The differences between these approaches become apparent when considering other factors such as:

- Value-sets, constraints and concept model alignment;
- Ease of requirements gathering;
- Relationship to clinical user interface design;
- Consistency of transformation rules across different models;
- Scalability and maintenance.

The following sections discuss each of these topics and the impact these have on evaluation of different approaches.

The principal conclusion is that specifying a particular structural approach of the types described in this section is in itself insufficient to deliver an effective, consistent and scalable *terminology binding*.

Section 5 recommends approaches that address these issues, while leaving some aspects of these structural questions open for further discussion.

6.4 Factors to consider in assessing alternative approaches

6.4.1 Value-sets, constraints and concept model alignment

The use of each attribute (or attribute bound element) needs to be appropriately constrained.

Simple use case specific constraints can be represented as independent value-sets which may be specified explicitly (e.g. as a list) or intensionally (i.e. a set of rules that determine membership). Where value-sets are specified in relation to SNOMED CT, it is recommended that these should be represented in the ways specified by SNOMED CT documentation (i.e. using either the Subset Mechanism or the proposed RefSet Mechanism).

> Both these mechanisms support simple subsets as well as more sophisticated hierarchical navigation sets. The RefSet Mechanism contains various enhancements, including provision for more effective version management and greater flexibility.

The simple value-set approach does not take account of the concept model which may specify additional constraints that are dependent on other concepts selected for inclusion in the same 'hr-unit'.

A minimum requirement is to conform to the general constraints in the concept model (e.g. to prevent use of attributes that are not permitted for concepts in a particular domain and to limit the range of values that can be applied to an attribute to those permitted by the concept model).

> For example, a finding cannot be refined with the 'method' attribute (with values such as 'excision – action'). However, it can be refined with the 'finding method' attribute (with values such as 'by auscultation').

A slightly more sophisticated implementation would further constrain the ranges to those that are compatible with the definition of the chosen concept.

> For example, if the finding type is 'liver failure' it cannot be refined by a finding site other that 'liver structure' and cannot be assigned a 'laterality' attribute.

Validating these rules in 'hr-unit' instances is straight forward if the 'hru-clinical' is expressed using a single slot containing a SNOMED CT expression. Otherwise it requires the binding between each of the separate slots and the relevant attribute of the concept model to be explicitly recognised.

6.4.2 Ease of requirements gathering

The way in which requirements are gathered does not necessarily need to reflect the form in which the content is represented (either in storage or at the user interface). However, a user-friendly approach to requirements gathering does need to be linked to options that can be effectively implemented.

Therefore, the type of tools used to design structural constraints should be linked to the relevant SNOMED CT concept model constraints. In particular, the available slots for coding the 'hru-clinical' should be bound to relevant SNOMED CT attributes and the value-set available for the populating these slots should be limited to those appropriate for refining other concepts in the 'hru-clinical' and should not be specified independently.

6.4.3 Relationship to clinical user interface design

Decisions made during requirements gathering are likely to influence the design of the clinical user interface. However, where SNOMED CT is used to specify the 'hru-clinical' this aspect of the user interface should be sensitive to the concept model.

> For example, selecting a particular concept from the value-set available for one field on a screen form, should appropriately constrain the available options for the user to refine that concept. These constraints should apply in addition to specific constraints in the archetype or template.

6.4.4 Consistency of transformation rules across different models

There are established rules for transforming SNOMED CT expressions to a common 'normal form'. The same rules could be applied to values stored in separate slots related to an archetype. However, this requires an additional step binding the specific slot in the archetype to the appropriate SNOMED CT attribute.

This is not particularly difficult if a) the archetype slot has a one-to-one relationship with a SNOMED CT and b) the value-set is constrained in accordance with the concept model rules for that attribute. However, if these either of these provisions do not apply, then:

> Provision (a) may be broken by use of the same archetype slot for representing types of refinement which may be regarded as similar by the archetype designer but which differ in the SNOMED CT concept model.
>
> > For example, the attributes 'method', 'finding method' and 'measurement method' have different meanings in SNOMED CT but an archetype designer without appropriate guidance might allocate a single slot 'method'.
>
> Provision (b) may be broken by permitting values that are not appropriate to a given attribute or which are inappropriate to that attribute when applied to a particular concept.
>
> > For example, a slot considered equivalent to the SNOMED CT attribute 'method' permits the value 'laparoscopic'.

6.5 Summary of options for granularity of terminology binding

6.5.1 Structural granularity of information model artefacts

The tables in this section identify different factors related to structural components that may influence the way in which binding needs to be expressed.

Table 6. Structural factors in terminology binding (part 1)

Factor	Description	
1 node	A single node in a template or archetype that contains information with a meaning that can be represented by a terminology expression. The values applied to each node may be specified in different ways.	
	Values	
	LIST	A template may specify a fixed list of values. Each item in the list binds to different single terminology expression.
	DOMAIN	A template may specify a general type of concept domain that can be expressed. The *terminology binding* specifies the set of possible expressions that can populate this node.
2 nodes	Two nodes in a template or archetype that when considered together have a meaning that can be represented by a single terminology expression. There may be different types of relationship between these nodes in the template and the values applicable to each node may be specified in different ways.	
	Relationships	
	Parent-Child	A node and a descendant node that, when considered together, have a meaning that can be represented by a terminology expression. For example, the parent may specify contextual information such as family history and the descendant may identify the disease.
	Siblings	Two nodes that are descendants or a common node that, when considered together, have a meaning that can be represented by a terminology expression. For example, one may specify a symptom and another whether it is present or absent.
	Values	
	LIST	Both the template nodes have a specified fixed list of values. Terminology binding may be effected either: a) By identifying a binding for each item in the cross-product of the two lists; or b) By identifying bindings for each of the nodes and the way that these relate together in the terminology expression.
	MIXED	One template node has a specified fixed list of values. The other node is specified as a code within a specified domain. Terminology binding should specify: a) The value set of terminology expressions for the domain limited node; and b) Rules that determine how the meaning from the fixed list modifies the resulting expression.
	DOMAIN	Both template nodes specify a general type of concept domain that can be expressed. In this case, the way values are selected for the two nodes may create a huge range of possible meanings. Terminology binding is only practical if it is possible to specify: a) A value set of terminology expressions for each of the nodes; and b) Rules for combining the two resulting expressions in a rational manner.

Table 7. Structural factors in terminology binding (part 2)

Factor	Description	
3+ nodes	Three or more nodes in a template or archetype that when considered together have a meaning that can be represented by a terminology expression. There may be different types of relationship between these nodes in the template and the values applicable to each node may be specified in different ways.	
	Relationships	
	Par-Children	One node may have all the other relevant nodes as its descendants.
	Nested GP-Par-Child	One node may have another node as a descendant and that node may have one or more other nodes as its descendants.
	Siblings	All the nodes have a common ancestor node.
	Values	
	LIST	Each of the template nodes has a specified fixed list of values. Terminology binding may be effected either: a) By identifying a binding for each item in the cross-product of all the lists; or b) By identifying bindings for each of the nodes and the way that these relate together in the terminology expression.
	MIXED	Some template nodes have specified fixed lists of values. The other nodes are specified as a code within a specified domain. Terminology binding should specify: a) The value set of terminology expressions for each of the domain limited nodes; and b) Rules that determine how the values from the fixed lists modify the resulting expression; *and if more than two nodes are domain limited* c) Rules from combining the expressions resulting from the domain limited nodes.
	DOMAIN	Each template node specifies a general type of concept domain that can be expressed in that node. In this case, the way values are selected for the two nodes may create a huge range of possible meanings. Terminology binding is only practical if it is possible to specify: a) A value set of terminology expressions for each of the nodes; and b) Rules for combining the resulting expressions in a rational manner.

Table 8. Additional structural factors in multi-node terminology bindings

Factor	Description	
Split nodes	Where two or more nodes provide the meaning for a single terminology expression, it is possible that some nodes in the template may be involved in two or more *terminology bindings*. There are several possible relationships between these shared nodes and these may affect decisions on where in the structure a derived expression should be bound or represented.	
	Relationship	
	Shared parent	A parent node may be involved in separate *terminology bindings* in concert with a different descendant node (or set of nodes). For example, if a node specifies differential diagnosis and contains two different representations (one list limited and the other domain bound) the parent node is separately bound to both nodes.
	Split siblings	Some sibling nodes may be involved in adding detail to one concept (e.g. severity might be combined with a finding concept in a single binding) while other sibling nodes express additional information expressed as a separate terminology expression (e.g. exacerbating factors).
Dependent value sets	Where two or more nodes are relevant to *terminology binding*, the value applied to one node may alter the rational set of values applicable to the other node (for example, it would be rational to apply laterality to pneumonia but not to appendicitis). The SNOMED CT terminology model supports this type of dynamic constraint on post-coordinated expressions. However, if the template provides separate nodes for these items of data, the *terminology binding* rules need to adapt to the underlying concept model. Note: This is not about what it is 'rational, sensible or correct to say' (i.e. knowledge related) but what it is logically possible to say (i.e. based on concept definitions).	
Domain overlap	It is possible that some domain constrained nodes will permit the inclusion of expressions that specify detailed information for which the template also provides a specific node. (For example a template might provide a node for disorder and a separate node for body site. Some conditions have a fixed body site - 'appendicitis' and SNOMED CT also supports localizing any finding to a site using a post-coordinated expression.) In these cases, *terminology binding* might specify rules for either automatically populating or omitting nodes that have values implied by the expressions in another node.	

6.6 Expressive granularity of terminology components

The tables in this section outline the terminology related factor that may be involved in binding to the structural components summarised in the previous section.

Table 9. Terminology factors in binding to structural models (part 1)

Factor	Description	
Expression complexity	The SNOMED CT expression bound to a node or set of nodes will consist of references to one or more SNOMED ConceptIds. The range of potential complexity is summarised below.	
	Pre-coordinated	An expression consisting of a single conceptId
	Post-coordinated (minimal)	An expression consisting of a conceptId with one or more refinements specifically allowed by the template (e.g. laterality, severity).
	Post-coordinated (full)	Any expression that conforms to the SNOMED CT concept model and falls within the concept domain specified by *terminology binding* but is not otherwise restricted. These expressions may include nesting.
	Expression forms and transformation	The form of the expression bound to a node in the structure would usually be the lightweight form referred to in SNOMED CT documents as 'close-to-user form'. The 'normal form' that is optimised for retrieval is not recommended for primary storage and communication for a variety of reasons[19].
Representing situations and context	The SNOMED CT expression bound to a node or set of nodes that are intended to convey information about a finding (including diagnosis) or a procedure may include representation of the relevant situational context.	
	Explicit context	The explicit context can be represented either in its full form using the relevant set of context attributes or by using a high-level concept in the relevant 'situation with explicit context' hierarchy and refining this with the appropriate 'associated finding' or 'associated procedure'. The latter approach provides a shorter, clearer expression in many cases, but there are some aspects of context that current still require the longer form.
	Default context	It is also possible to use the default context 'present' and 'done' without stating this explicitly. Thus 'appendicectomy' means 'appendicectomy done' unless otherwise stated.
	Structure dependent context	Use of an expression in relation to a particular node may imply a particular explicit context. In these cases, the binding needs to capture or map the relevant contextual information unless it is explicitly repeated in the coded expression

[19] These reasons are discussed in detail in SNOMED CT documents and are not repeated here. However, they relate to quality and reliability factors not just storage size. The normal form can and should be generated from close-to-user form using the most up-to-date version of the SNOMED CT definitions available at retrieval time.

Table 10. Terminology factors in binding to structural models (part 2)

Factor	Description	
Value Set specification	The SNOMED CT expression bound to a node or set of nodes may be chosen from a fixed set of values or may be derived from an intensional definition. Note that the values specified by any of these methods may be pre-coordinated or post-coordinated and may contain contextual information (see Table 9) The potential ways of specifying value sets are summarised below.	
	Fixed	A single expression bound to a given value for a node in the template.
	List (Extensional definition)	A list of expressions that can be entered as values for a given node in the template.
	Constraints (Intensional definition)	A set of rules that specify the range of possible expressions that can be entered. Possible representations of these types of constraints have been suggested by HL7 TermInfo and extended by John Arnett in his work on adverse reaction *terminology binding*. Further work tying this to a machine readable representation of the SNOMED CT concept model is being undertaken by a Project Group of the IHTSDO.

6.6.1 Representing terminology bindings

Representation of bindings needs to consider the intersection range of structural (Table 6 to Table 8) and terminological factors (Table 9 to Table 10).

Rather than representing the binding one code to one node, there is a requirement to represent the roles that multiple nodes play in building one or more terminology expressions.

In addition, the way that *terminology binding* assists and constrains the capture of information needs to be considered. While the interdependencies between nodes in the template present a challenge, it also presents a significant opportunity to rationalise data capture, so that the content requirements are met to an appropriate level of detail in each case.

7 Types of terminology binding

Terminology binding refers to any linkage between one or more components of an information model and one or more components from a terminology.

Several distinct types of *terminology binding* can be identified. Each type of binding has a role to play in the overall task of improving semantic consistency and hence providing a foundation for interoperability. Some differences of view about '*terminology binding*' requirements arise from a focusing on one type of linkage between structure and terminology.

> For example, some people have expressed the view that all *terminology bindings* can be expressed in relation to archetypes, while others assert the need to terminology bind templates. This 'archetype only' view of binding is only sustainable for particular types of *terminology binding*. As discussed in 7.6, *terminology binding* in its broader sense must also be applicable to templates.

The following points identify specific types of '*terminology binding*' so that the full breadth of the scope can be considered. This allows the different requirements for each type to be addressed individually in ways that are consistent.

7.1 Constraint bindings

7.1.1 Semantic constraint binding

Semantic-constraints restrict what it is possible say

A semantic-constraint binding asserts that only terminology expressions that have a meaning that falls within a domain specified by the constraint can be applied as values to a particular node of an archetype (or template).

The domain for a binding may be specified in one of two ways:

- As a complete set of concept identifiers (extension).
- As a set of rules that test relationships between concepts in the terminology to determine the membership of the set (intensional).
    - The rules may vary from simple rules such as 'this concept and all its subtypes' to more complex rules that involve presence or absence of particular defining relationships and or expression refinements.

A semantic-constraint is concerned with ensuring that the expression used conveys a meaning that is appropriate to the structural component.

Examples

- A node representing diagnosis might be required to be a value that is a subtype of [64572001 | disease]

A semantic-constraint may explicitly require or exclude a particular facet of information to be expressed.

Examples

- A node describing a procedure on a kidney might be required to specify laterality.
- A node representing the action of administering a drug may be required to exclude any mention of the substance administered, as this may be expressed in a separate node.

    Thus [32282008 | subcutaneous injection] would be permitted but not [308755006 | subcutaneous injection of insulin].

A semantic-constraint is not concerned whether that meaning is conveyed as a pre-coordinated or post-coordinated expression.

Examples

- If [71620000 | fracture of femur] is valid then an equivalent post-coordinated expression would also be valid (e.g. [125605004 | fracture of bone | : 363698007 | finding site | = 71341001 | bone structure of femur]).
- The requirement to specify laterality for a kidney procedure would be met by any of the following

    a) [108022006 | kidney excision | : 272741003 | laterality | = 7771000 | left]

    b) [65801008 | excision | : 405813007 | procedure site - Direct | =
    (64033007 | kidney structure | : 272741003 | laterality | = 7771000 | left |) }]

    c) [65801008 | excision | :
    405813007 | procedure site - Direct | =18639004 | left kidney structure]

Semantic-constraint bindings are inherited by the same node in any artefact derived from the artefact in which the binding is expressed.

Derived artefacts may have additional semantic-constraints that further refine the range of possible expressions but they may not extend the range of permitted expressions.

Wherever possible, semantic-constraints should be expressed using a standard formalism that is specified or recommended by the terminology.

- SNOMED CT mechanisms for representation of sets (Subset and their enhancement as Refsets) can meet most of the simple requirements for specifying semantic constraints.
- More sophisticated constraints such as a requirement or prohibition of a particular facet of information require a more expressive syntax. The IHTSDO 'Machine Readable Concept Model (MRCM) Project' should provide this in the next few months. In the meantime, the extensions of the SNOMED CT compositional grammar proposed by TermInfo and the added facility to reference Subsets (or Refsets) as proposed by John Arnett can be used.

7.1.1.1 Semantic constraint binding and the SNOMED CT concept model

As a general rule, all constraint bindings should be refinements of the concept model. Alignment of representation with the MRCM should assist validation of conformance and exception reporting.

7.1.2 Expression-structure constraint binding

Expression-structure constraints restrict how it possible to say something

An expression-structure constraint specifies the permitted or required post-coordination of an expression that may be applied to the value of a particular node of an archetype (or template).

Examples

- Prohibition of any post-coordination:

  [71620000 | fracture of femur] is permitted but semantically equivalent post-coordinated expressions (e.g. [125605004 | fracture of bone | : 363698007 | finding site | = 71341001 | bone structure of femur]) are not permitted.

- Requirement for the substance responsible for an allergy to be represented by post-coordination:

  [106190000 | allergy | : 246075003 | causative agent | = 373270004 | penicillin -class of antibiotic-] is permitted but the semantically equivalent pre-coordinated concept [91936005 | allergy to penicillin] is not permitted.

Expression-structure constraints are related to semantic constraints. An expression-structure constraint imposes some constraints on semantics (e.g. if post-coordination is not permitted, then meanings for which no pre-coordinated concept exists in SNOMED CT cannot be represented). Similarly, a semantic-constraint may indirectly constrain the expression-structure (e.g. if the prohibiting a specific semantic facet prohibits that aspect of post-coordination).

Despite these interdependencies, expression-structure constraints can vary independently of semantic-constraints and address different requirements.

Examples

- Post-coordination may be prohibited or constrained to limit the potential complexity of expressions to fit within a given record structure, even though it would be semantically rational to include refinements.
- Post-coordination of a particular attribute may be required to force a common structural pattern for representation of particular concepts, even though some pre-coordinated concepts could express the same meaning.

Expression-structure constraints can be used to limit variation in forms of expression and thus simplify implementation. However, unlike semantic-constraints they can vary in different ways that do not alter the interpretation of the meaning.

7.1.2.1 Expression-structure constraint binding and the SNOMED CT concept model

Expression-structure constraints should align with the concept model.

For example, if laterality is required for procedures or findings, this requirement should not apply if the site is a non-lateralisable body structure according to the concept model.

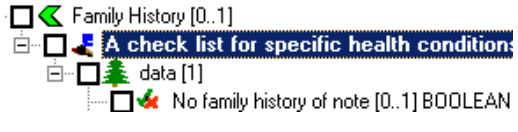
7.2 Fixed bindings

7.2.1 Node-fixed bindings

Node-fixed bindings assert that inclusion of a node has a specified fixed meaning

A node-fixed binding specifies the SNOMED CT expression that is applied if the bound node is included. In the case of a node with a Boolean value the expression is applied if the node has the value 'true'.

For example, in Figure 11 if the node 'No family history or note' has the value 'true', the relevant SNOMED CT concept applies as shown.



160266009 | no significant family history |

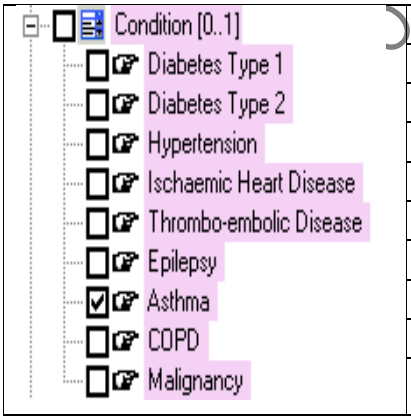
Figure 11. No significant family history

7.2.2 Choice-fixed bindings

Choice-fixed bindings assert that a given choice from a list has the specified meaning

A choice-fixed binding specifies the SNOMED CT expression that is applied if the specified choice is selected from the list of available options.

For example, in the list shown in Figure 12 each of the choices in the list relates to a single SNOMED CT concept. Each of these concepts is a subtype of 'disease' and the condition node as a whole has a semantic constraint binding specifying this domain.



<64572001|disease| *(semantic constraint binding)*
46635009|diabetes mellitus type 1|
44054006|diabetes mellitus type 2|
38341003|hypertensive disorder|
414545008|ischaemic heart disease|
371039008|thromboembolic disorder|
84757009|epilepsy|
195967001|asthma|
13645005|chronic obstructive lung disease|
86049000|neoplasm, malignant (primary)|

Figure 12. Conditions node with choice-fixed bindings

A possible alternative to 'choice-fixed' bindings using Subset/Reference sets is suggested in 7.3.

7.3 Selection support bindings

Archetypes and templates contains lists of terms that serve one or more of the following roles.

a) Check-lists of items that each require a response

b) Choices of values with no option to select additional values

c) Choices of values with the option to select alternative values

    - In the templates reviewed, this type of functionality is supported by including one node limited to members of list and an addition text node.

There are several other ways in which selection could be supported by lists or sets. These include:

d) To provide easy access to the most commonly used concepts (or descriptions) used in a particular data collection context.

e) To provide an alternative selection hierarchy to refine selected items.

f) To provide similar assistance with post-coordination (i.e. lists of appropriate values for refinements).

There appears to be an opportunity for a more efficient approach using Reference Sets to identify the relevant sets of components (concept or descriptions) to be displayed in the list. Associated metadata could indicate the particular role of the list and its members (e.g. favourites, limited list of values, etc).

The main advantage of this approach would be that the *terminology binding* and list specification would be accomplished with a single step.

Another possible advantage is the ability to vary lists for different environments without changing the archetype or template. This facility may simplify maintenance in some cases. However, it would have to be applied with care (i.e. in many cases the sets specified would need to be locked to the template).

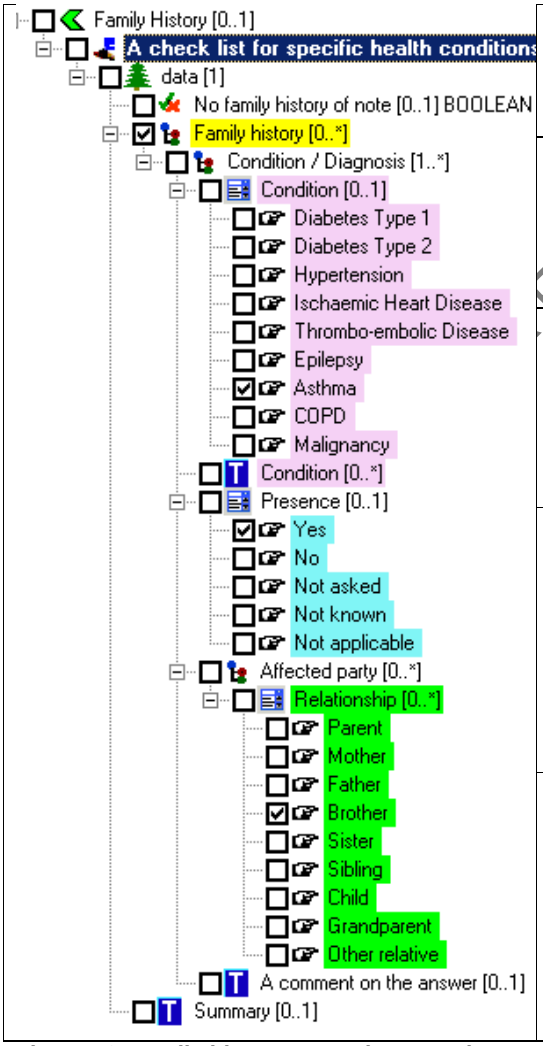
7.4 Constructor bindings

Constructors are guides for assembling expressions from a set of related nodes

A constructor binding provides a framework indicating how the value or set of related nodes should be combined into a compositional expression.

Constructor bindings are required to provide a consistent *model-of-meaning* in cases where different nodes contribute to the meaning.

Figure 13 and Figure 14 illustrate the way that constructor bindings can be applied to the archetype 'openEHR-EHR-EVALUATION.check_list-condition-third_party.v2' (as used in template 'ENTDischarge.v3') to represent 'Family history' in a manner that is consistent with the SNOMED CT Concept Model for clinical situations.



Each instance of the **Family history** node represents an item of positive or negative family history which SNOMED CT expresses as a [243796009 | situation with explicit context].
The full expression that represents this depends on the values assigned to three subsidiary nodes. o condition o presence o relationship
The **condition** node provides the 'associated finding' attribute for the SNOMED CT expression. This value may be either: o Selected as a choice from a list; or o Choosing any disease concept from SNOMED CT.
The **presence** node provides the 'finding context' value for the SNOMED CT expression. o There are directly equivalent values for 'Yes', 'No' and 'Not known' o Issues related to 'Not asked' and 'Not applicable' are discussed elsewhere in this document.
The **affected party relationship** node provides the 'subject relationship context' value for the SNOMED CT expression.

Figure 13. Family history example - overview

7.4.1 Representing constructor bindings

It is relatively straight-forward to specify constructor bindings that cover the majority of cases. A constructor can be represented as an expression that includes path expressions identifying the source of the constituent values.

Figure 14 shows the draft syntax applied to the family history nodes in Figure 13 to return the resulting expression Figure 15. The bold coloured paths are replaced by the choice-fixed bindings for the nodes identified by the paths.

243796009 | situation with explicit context | :
{246090004 | associated finding | = **$**
items[@node_id='at0002']/items[@node_id='at0.2']/code
*items[@node_id='at0002']/items[@node_id='at0003']**$***
,408729009 | finding context | = **$items[@node_id='at0002']/items[@node_id='at0.12']/code$**
,408732007 | subject relationship context | =
$items[@node_id='at0002']/items[@node_id='at0.0.16']/items[@node_id='at0.0.17']/code$}

Figure 14. Draft examples of constructor representation

at0004	**Family history** [0..*]	**243796009 | situation with explicit context | :** {246090004 | associated finding | = **195967001|asthma|** ,408729009 | finding context | = **410515003 | known present |** ,408731000 | temporal context | = 410512000 | current or specified | ,408732007 | subject relationship context | = **70924004|brother|**}
at0002	Condition / Diagnosis [1..*]	
at0.2	Condition [0..1]	<64572001|disease|
at0.9	**Asthma**	**195967001|asthma|**
at0.12	Presence [0..1]	
at0.13	**Yes**	**410515003 | known present |**
at0.0.16	Affected party [0..*]	
at0.0.17	Relationship [0..*]	<125677006|relative|
at0.0.21	**Brother**	**70924004|brother|**

Figure 15. Family history example - selected values and resulting expression

7.4.2 Issues with constructor bindings

The draft representation to constructor bindings provides an effective approach that works in most cases. However, the following issues were identified:

a) Specifying how the expression should be constructed when optional list items are not selected.
    - E.g. defaulting to 'relative' as a default value if the affected party is not specified in Figure 13.

b) Construction of an expression when a choice exists between a list and a free-style entry
    - E.g. when the second 'condition' node in Figure 13 is used to specify another concept from SNOMED CT rather than using a list item.

c) Lists that contain values that imply orthogonal or dissonant meanings.
    - E.g. the 'Presence' node values 'Yes', 'No' and 'Not known' are rational responses to the question 'is the condition present in a family member'. In contrast, the values 'Not asked' and 'Not applicable' while understandable as responses on a form, are semantically distinct – 'Not asked' is a reason why the answer is unknown and the meaning of 'Not applicable' may mean "not asked because it wasn't relevant" or may mean there is a reason why it could not be present and thus is not worth considering or recording.

d) Interdependencies between nodes that alter the construction rules.
    - In theory, it would be possible for different construction rules to apply according to the values in two or more nodes. However, apart from the dissonant value sets discussed in (c) no examples of this have been found so far.

The italicized path in the magenta coloured section of Figure 14 represents an alternative source of a value when an item is not selected and thus does not return a bound value. This approach deals with issues (a) and (b).

Issue (c) is more difficult and raises additional challenges because the dissonant values may suggest additional contextual information that applies to regular values.

- E.g. the value 'Presence' = 'Not asked' implies 'Not known' in the sense that the record is unable to answer the question 'does the patient have a family history of asthma'. However, it also explicitly records that something was not done (the question was not asked). This would seem to imply that that the value 'Not known' in the list means 'Asked but still not known' ('Patient refused to answer', 'Patient said they did not know' or even 'Patient answered but I am not confident the answer they gave is correct').

7.5 Retrieval bindings

Retrieval binding determines what information is used to pre-populate a display node

Retrieval bindings specify criteria for retrieving existing information from a record to automatically populate (or suggest a value for) a particular node or set of nodes.

This type of binding is relevant if the content specification is concerned with the information required, rather than the information that has to be specifically recorded. If the objective is to reuse information rather than duplicate it, there is a requirement to specify the criteria for populating the field.

In some cases, the constructor, constraint and fixed bindings may provide adequate information to enable pre-population.

> For example, a previous record entry that matches (or is subsumed by) the constructed binding expression for family history of asthma, might be used to pre-populate the relevant family history item.

In other cases, the criteria for pre-population may need to take account of other factors, such as timing and certainty associated with previous record entries.

> For example, in Figure 16 entering the presenting symptom as 'Chest pain symptom' might reasonably be expected to populate the 'Review of systems checklist entry' for 'chest pain'. However, a record of 'chest pain' in a previous encounter note could not be used to complete the check list for this encounter.

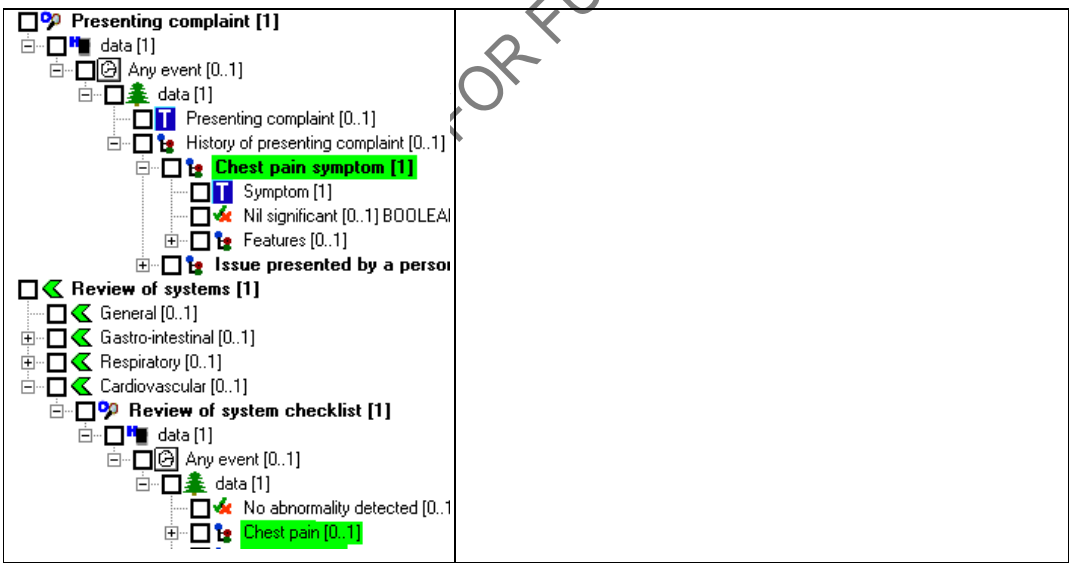


Figure 16. Chest pain as presenting complaint

7.6 Terminology binding and templates

Current openEHR facilities for *terminology binding* apply only to archetypes. During discussions some participants have expressed the view that *terminology binding* is only needed on archetypes while others have suggested there are requirements for binding to templates. One reason for this seems to be differences in understanding of the scope of *terminology binding*.

- It seems reasonable to assert that semantic constraint bindings 7.1.1 should apply to archetypes and be inherited by templates.
    - However, there may be a case for refinements of these constraints to be expressed in templates.
- Since templates do not add structural elements, it should also be possible to place all constructor bindings 7.4 in archetypes.
    - There is a risk that additional labels and renaming of nodes may lead to dissonance in lists which might lead to a need for exceptions in templates. However, it would be preferable to invest effort in preventing this dissonance rather than creating additional constructor binding variants in templates.
- Lists of options are currently expressed in templates and these create a requirement for node-fixed bindings (7.2.1) and choice–fixed (7.4) or selection support bindings (7.3) to be supported either in, or linked, to templates.
    - Selection support bindings (7.3) that can be locally constrained to match particular user preferences tend to favour the idea of a separate referenced report.
- Expression-structure constraint bindings (7.1.2) are likely to be required in template (rather than or as well as in archetypes). The reason for this is that these types of constrain are likely to be driven by particular models of use and business requirements.
    - It may also be useful for some of these constraints to be varied locally to align with a particular implemented information model.

8 Standards background

8.1 Use of different standards

The NHS is applying different combinations of standards to different aspects of clinical information. These include:

- IHTSDO Terminology Standards
    - SNOMED Clinical Terms® to represent the meaning of concepts used within clinical records and clinical communications.
- HL7 Version 3 Standards
    - Clinical Document Architecture (CDA) to represent and exchange clinical records as a series of 'documents' that mix textual sections and structured entries (i.e. clinical statements).
    - Clinical Statements to represent the structured entry classes in CDA and supporting other structured communications.
    - Templates to constrain particular CDA entries (and clinical statements) to increase the consistency of structured communication of specific types of information.
    - TermInfo "Guide to the Use of SNOMED CT in HL7 Version 3", to inform decisions on binding between SNOMED CT concepts and HL7 classes and attributes.
- CEN EN13606 Standards
    - Archetype definitions, based on EN13606-2 (as supported by openEHR tools), to model detailed constraints for clinical data capture.
    - This technique is also being considered to model detailed constraints for data display.

Each of these standards has its strengths and weaknesses. The case for using a mix of different standard depends on making use of the strengths of each standard. The most obvious challenge of the mixed approach relates to the gaps and overlaps between them. Additionally, there are issues that arise from gaps in the communication between experts who focus on particular standards (see 8.2).

Another significant factor is the way that work done to bridge the gap between standards contributes to and utilises the evolutionary enhancements of the base standards. In some cases, contributing to enhancements of a standard may be more beneficial than applying a local patch or work-round. Even where timing issues may prevent this approach, it is usually worth seeking an informal consensus on the types of approach that are least likely to inhibit future convergence. This is particularly likely to be fruitful in respect of SNOMED CT where the Concept Model, Editorial Guidelines and IHTSDO discussions on known issues may inform decisions on local content extensions that meet particular requirements.

8.2 Problems of perspective and language

The technical issues posed by bringing together different standards are accentuated by the different perspectives of experts in particular standards communities. These result from a combination of:

- Different views of the priority of particular issues.
  - Different perception of priorities may be the reason for involvement with one standard rather than another, and may be reinforced by the focus on work on particular issues within a like-minded community.
- Different levels of knowledge of the individual standards.
  - Those actively working in one field have an intimate knowledge of the standard they are working with at the time. However they rarely have the time to keep similarly up to date with progress in other communities.
- Different use of language (community jargon)
  - For example, differences in use of terms including, "attribute", "post-coordination", "procedure" by HL7 and SNOMED communities were identified and documented by TermInfo.
  - Similar issues arise from different understanding of words such as "attribute", "concept", "definition", "description", "domain", "expression", "term", "primitive" used in SNOMED CT, which have other meanings in ENV13606-2 archetypes.

These issues combine to create a risk of misunderstanding of the purpose, value and use of components of another standard. Therefore, an important step towards effective bindings and transformation is to both give and receive education – rather than assuming everyone has or should have a common level of knowledge.

Where different meanings for similar words are identified, these differences need to be clearly stated and respected. Arguing for one meaning to prevail is likely to lead to unnecessary contention and risks simply creating another community of expertise with a hybrid jargon. Deviation from the mainstream use of jargon in the contributing standards is unlikely to assist convergence.

8.3 Practical and theoretical considerations

NHS CFH needs to ensure that the standards it specifies and the bindings or transforms between them can meet its practical objectives. This requires support by software applications that are (or will soon become) available for widespread use in the NHS. These applications need to address the needs of their uses in different specialties, disciplines and environments as well as the overall requirements of the NHS.

While practicality is a key factor, decisions dictated by limitations in existing systems will not facilitate the semantic interoperability needed to meet the stated objectives of NHS CFH. Therefore, a multi-threaded approach to *terminology binding* and information model transformations is likely to be needed.

- The primary strand should focus on an approach which is robust and realistic as a medium term solution. This strand should not seek some notional 'perfection' but should be informed by what is known to be computationally practical and logically consistent with evolving standards. The primary recommendations should thus be known to be implementable but may not have been implemented in existing systems.
- In the secondary strand, any absolute and immediate needs will inevitably be addressed with pragmatic short-term compromises that accept the limitations of existing systems. The compromises made should, where possible, be informed by the primary recommendations and the strategy for migration to the preferred approach.

9 SNOMED CT background information

TO BE EXTENDED

Comment [DM1]: This section will be populated with relevant excerpts from and/or references to relevant SNOMED CT and IHTSDO materials.

9.1 Terminologies, terms, concepts and bindings

This paper relates to the way in which elements of a *terminology* are bound to elements of an *information model* in order to ensure consistent representation of meaning.

For reasons of brevity *terminology binding* is sometime referred to as "term binding". However, this is misleading as binding is not to *terms* (strings of characters forming phrases or sentences) but to representation of *concepts* within the terminology. For example:

- The *terms* "appendicectomy" and "removal of appendix" both describe the same underlying *concept*.
- The *term* "leg" may refer to two significantly different *concepts*
    - "the part of the lower limb between the knee and the ankle" (the formal anatomical definition used in medical dictionaries).
    - "the lower limb" (the more conventional understanding).

To minimise it is strongly recommended that the phrase 'term binding' should **not** be used.

9.2 Representation of sets

SNOMED CT Subsets, Reference Sets, Explicit lists of member, Set definitions (intensional) rules, ad-hoc value-sets. Pros and cons of each.

9.3 SNOMED CT Concept Model

Short outline with references to more detailed material.

In future this should link to Machine Readable Concept Model representation for live documentation.

9.3.1 Representation of post-coordination constraints

SNOMED CT Machine Readable concept model work status (including Jeremy Rogers and Guillermo Reynoso practical examples).

TermInfo extension of compositional grammar for limited constraint expressions.

9.3.2 Close to user representations

Advice on use of close-to-user forms to ensure data capture does not add excess modeling information and thus lock-in the problem of normalised expressions.

9.3.3 Validation through SNOMED CT transformations

Use of SNOMED CT transformation to normal form as part of validation of post-coordinated constraints.

9.4 Cross Mapping considerations

Impact of bindings on data items that may need to be mapped to ICD10 or OPCS4.

9.5 Aligning structural granularity and post-coordination

9.5.1 Attribute semantics

Approach to dealing with cases when archetypes replicate (or are similar to) attributes in the SNOMED CT concept model.

9.5.2 Additional post-coordination constraints

Constraining post-coordination that may be semantically valid where this conflicts with mandatory requirements for additional classes.

9.5.3 Aligning post-coordination

Combining and structuring in ways consistent with TermInfo and CFH guidelines for communication representations.

9.5.4 Managing specific non-computable equivalents

Cases where two expressions (which seem to have the same meaning) cannot be computationally compared. Why it happens. The binding and constraint choices likely to minimise these problems.

9.6 Context and clinical situations

9.6.1 Alternative representations of context and clinical situations

Ensuring consistent representations can be generated from archetype plus SNOMED CT representation. Avoiding conflicting representations.

9.6.2 Avoidance of 'double context'

9.7 Areas of specific concept model weakness

9.7.1 Subject relationship context values

9.7.2 Negations in relation to context

9.7.3 Observable entities, evaluations procedures and related findings

9.7.4 Substance hierarchy

9.8 Other active concept model topics

9.8.1 Administration of substances

9.8.2 Severity and other relative attributes

9.8.3 Anatomy and body sites

9.8.4 Authority dependent concepts

9.9 Addressing gaps and issues identified in SNOMED CT

How to manage these issues as they arise during specification of archetypes and bindings.

9.9.1 Missing content

Content that really is missing.

Temporary patches.

UK extension options.

Request submission process.

Understanding the editorial rules for new content.

9.9.2 Content required due to technical limitations

Pre-coordinated content needed due to application issues with post coordination.

9.9.3 Concept model attribute limitations

Lack of attributes

Over restrictive constraints on attributes and ranges

9.9.4 Concept model logical limitations

Issues with computation of equivalence and subsumption etc.

Limitation of transformations

Appendix A: Relevant pre-existing material

A.1 Introduction

This appendix contains two contributions to the original report from Ed Cheetham. Both of these have direct and immediate relevance to the questions addressed by this document.

A.2 Guidance on the use of SNOMED CT in archetype development

Formerly published in CEN/ISO 13606 Pilot Study Final Report as Section 4.1.3 by E. Cheetham

At least three major headings are required to structure guidance on the use of SNOMED CT in archetype development:

- Vocabulary domain constraints
- Archetype/expression normalisation
- Guidance on overlaps

These sections are analogous to those used in the TermInfo paper, although the eventual weighting are likely to be different – notably because HL7 Version 3 has significantly more RIM-derived attributes that correspond to/overlap with attributes present in SNOMED CT. The TermInfo paper also has an extensive 'common patterns' chapter – it is unclear at this stage whether emulating such a section is needed, or whether by their very nature particular Archetypes will become the 'common patterns' With slightly more explanation:

Vocabulary domain constraints

This section will provide guidance on which classes/chapters of concepts from SNOMED CT would optimally be used in which settings and may be found in Appendix B.

Archetype/expression normalisation

This section will explore the steps needed to transform Archetype-structured clinical concepts into equivalent SNOMED CT-structured concepts to enable consistent analysis. It is the thesis of this section that:

1. Even when widely shared across any healthcare enterprise, the binding of archetype nodes to SNOMED-CT will not cover all the ways that the same clinical notion will be captured for SNOMED CT-encoding (free text analysis/graphical capture may also be used).
2. Given their design methodology (which deliberately includes a consideration of in-use/workflow optimisation), it cannot be assumed that all archetypes will be built in a way that is conspicuously isomorphic with (or implicitly transformable into) an equivalent SNOMED CT construct.
3. Unless transformations to a SNOMED CT-conformant form are included as part of the archetype, the substrate for additional SNOMED CT-normalisation rules and subsequent analysis will not be predictable.

These issues are explored further within the wider section **Archetype design considerations and transformation requirements** which also discusses the need to consider other aspects of Archetype-based systems at design time.

Guidance on overlaps

In order to check for any systematic overlaps, there is a need for detailed review of the 13606-3 Termlists to ensure that any potential overlaps between SNOMED CT-representations and 13606 values in information model attributes are actively managed. This is of particular importance to avoid conflicting record extract creations and in providing guidance (if desirable) for the creation of semantically-optimised 'SNOMED CT-only' representations of 13606/SNOMED CT constructs. This section has not yet been pursued and is therefore not considered further in this paper.

A.3 Vocabulary domain constraints (E. Cheetham)

Formerly published in CEN/ISO 13606 Pilot Study Final Report as Appendix B by E. Cheetham

Whilst there are probable editorial boundaries between what constitutes the sensible scope of an Archetype and what constitutes a Template, as well as similarly probable boundaries between what constitutes the 'clinical statement' part of a record entry and what constitutes its record structural context, two potential complexities are apparent when faced with the task of associating SNOMED CT content with an Archetype:

- Each Archetype may be designed with some degree of containment for its components – notably through the recursive use of CLUSTER components to represent a valid clinical statement. Such structures require clear editorial boundaries as to 'where' within them the SNOMED CT bindings are to be made, and (where bindings are unavoidably made at CLUSTER and ELEMENT levels) a consistent approach (possibly including transformations – see below) is needed for analysis purposes.
- There is effectively no limit on the nature/names of the ELEMENTS that can be identified for a given ENTRY (for a 13606 Archetype or ENTRY subtype for an openEHR Archetype). A not inconsiderable proportion of the ELEMENTS identified during Archetype design have either exact (or near-exact) analogues as SNOMED CT defining attributes, or have some or all of the differentia they represent available as primitive notions in SNOMED CT. Unless *all* SNOMED CT-encoded data for an Archetype-using enterprise is captured using Archetypes there is a need for an approach that:
    - Hides from use any SNOMED CT-content that primitively represents ELEMENT-and-value-represented Archetype data
    - Consistently allows detection equivalence between Archetype-conformant and Archetype-alternative representations

Both the above are non-trivial issues, and require a close collaborative Archetype development approach, as well as the development of systematic approach to addressing specific issues such as missing terminology content and a preferred representation of NULL entries, however as a start the following guidance is suggested for the binding of SNOMED CT to various ELEMENT-name and ELEMENT-value patterns.

Despite the provision of such constraints, it is the author's conviction that they will not alone guarantee semantic interoperability or predictable/consistent design/SNOMED CT binding by independent Archetype developers for similar requirements specifications. Any representations that are expected to be managed Nationally will need to have their detailed design coordinated Nationally. Until guidance constraints become suitably precise to ensure consistency and/or until alternative available representations of similar clinical notions in SNOMED CT are machine detectably equivalent (preferably within the reference data but arguably this can be compensated for by inclusive retrieval specifications) the opportunities for non-comparable technical representations of similar clinical requirements will persist.

At its simplest an Archetype ENTRY is represented as an ELEMENT. In the design process and artefacts produced, each ELEMENT has a name and an associated value (or, more appropriately for Archetype design, a set of suitable values). As explored below in the section '**Incomplete input grammar…**', a recurrent problem with Archetype design (but not exclusively with Archetypes – the same problem pattern is found in NHS 'clinical datasets' and in the HL7 'code/value' debate) is how to distribute the SNOMED CT semantics between the ELEMENT-name and ELEMENT-value. The guidance below emphasises a pattern that preferentially puts the semantics in ELEMENT-value unless the value is a numeric. This emphasis exploits SNOMED CT's 'strong suits' of 'findings' and 'procedures' (strong in the sense that these chapters have more content to start with, a relatively richer definitional model than 'observable entities' and are more likely to result in the storage of data that is comparable to the same notions captured by, for example, free text processing into SNOMED CT), and in so doing risks situating the *terminology bindings* firmly in the 'model of meaning'. At first glance this might not appear to be a risk – surely we want *terminology bindings* to be all in the model of meaning, but as is discussed in '**For findings and disorders/procedures – the use of a coded ELEMENT-name**' and '**Archetype transformation into 'SNOMED-conformant semantic units**' below, it may be desirable (for various 'models of use') to specify standard terminology content for display and data capture purposes which is not actually used for storage.

A.3.1 Using SNOMED CT to document findings and disorders as an ELEMENT-value

Many OBSERVATION and EVALUATION entries can be represented as SNOMED CT 'findings or disorders', and it is therefore reasonable to specify that codes within the following constraint can be used as such:

CONSTRAINT 1: Concepts in the descent of 404684003 | Clinical finding (finding) can be used as ELEMENT-values where ELEMENT-name is not coded.

It is not the author's opinion that there is a reproducible top-level distinction as to which concepts in this set can be used as the values for EVALUATIONS and which can be used as values for OBSERVATIONS. Superficially it is tempting to say that concepts in the descent of 64572001 | Disease (disorder) should be captured as EVALUATIONS, but the boundary is not a clear one.

Given that, once captured in a record, there is no distinction for interpretation purposes between, for example, 162086005 | Tenesmus present (situation) and 267053000 | Tenesmus (finding), the following constraint should also be introduced:

CONSTRAINT 2: Concepts in the descent of 413350009 | Finding with explicit context (situation) can be used as ELEMENT-values where ELEMENT-name is not coded.

A significant exception pattern for CONSTRAINT 2 is if alternative Archetype-based machinery is used to capture other definitional nuances represented by the SNOMED CT context model. In particular if the NHS were to adopt an Archetype-based approach to family history representation, any SNOMED CT content that indicated a concept's relevance to a subject other than the subject of the record (e.g. 160407004 | Family history: Eczema (situation)) would have to be excluded.

Finally SNOMED CT contains a number of concepts in the descent of 272379006 | Event (event) which may make reasonable clinical statements. Many of these have their origins in the 'external causes of injury' chapters of ICD 9/10, so there is some debate as to their correct usage in clinical records (should they only be used according to the rules of the originating classifications?), but that does not stop them superficially having utility. How else could one record that a patient had been involved in a '418399005 | Motor vehicle accident (event)' without use of such codes? This therefore results in a third constraint:

CONSTRAINT 3: Concepts in the descent of 272379006 | Event (event) can be used as ELEMENT-values where ELEMENT-name is not coded.

It should be noted that 'event' concepts are not fully integrated into the SNOMED CT model (it is not clear how to say that someone was '*not* involved in a motor vehicle accident'), and some clinical concepts that might be thought of as 'events' (such as asthmatic attacks and epileptic seizures) are still classified as findings and disorders.

A.3.2 For findings and disorders – the use of a coded ELEMENT-name

The above constraints probably provide some satisfactory guidance, but, as has been indicated before, are incomplete for at least two reasons:

1. Some clinical content has to be captured using a coded ELEMENT-name (with a coded or numeric ELEMENT-value)
2. Some Archetype specifications may benefit from providing standard coded text for ELEMENT-names.

In support of reason 1, the following constraints are offered:

CONSTRAINT 4: Concepts in the descent of 363787002 | Observable entity (observable entity) OR 386053000 | Evaluation procedure (procedure) OR 108252007 | Laboratory procedure (procedure) can be used as ELEMENT-names where ELEMENT-value is either numeric or coded from the value set specified in CONSTRAINT 5.

CONSTRAINT 5: Concepts in the descent of 260245000 | Findings values (qualifier value) OR 281296001 | Result comments (qualifier value) can be used as ELEMENT-values where ELEMENT-name is coded from the value set specified in CONSTRAINT 4.

A particular caveat for CONSTRAINT 4 is that whilst 'Evaluation procedure' does subsume some suitable content, it also subsumes much that is unsuitable (many surgical procedures that would not naturally be an action that resulted in a value), so should be used cautiously.

A particular caveat for CONSTRAINT 5 is that the value set this specifies excludes a lot of apparently suitable content (the two nodes specified subsume ~200 concepts, as compared to potentially many thousands in SNOMED CT). For example this value set would not allow 247030006 | Color of iris (observable entity) to be associated with a value 405738005 | Blue color (qualifier value) to allow equivalence to be detected with 301952009 | Blue iris (finding) (even though equivalence is partially detectable via the relationship Blue iris: Interprets (attribute) = Color of iris (observable entity) in the reference data.

In support of reason 2, the following constraint is offered:

CONSTRAINT 6: Concepts in the descent of 363787002 | Observable entity (observable entity) OR 386053000 | Evaluation procedure (procedure) OR 108252007 | Laboratory procedure (procedure) can be used as ELEMENT-names where ELEMENT-value is coded from the value sets specified in CONSTRAINTS 1, 2 and 3.

The caveat for CONSTRAINT 6 is that this is a valid combination provided the code in ELEMENT-name together with the code in ELEMENT-value does not yield a meaning that is substantially different from the meaning if ELEMENT-name was not coded. For example, it may be helpful to have a standard 'question prompt' specified in the Archetype of 'Color of iris (observable entity)', where the stored values are the

finding codes 301952009 | Blue iris (finding), 301953004 | Brown iris (finding) and 301954005 | Green iris (finding). For interpretation the ELEMENT-name code is effectively redundant and non-disruptive semantically. By comparison, if the code 410551005 | Family history taking (procedure) were used in ELEMENT-name, this would be significantly disruptive to the interpretation of a 'finding' or 'disorder' code in ELEMENT-name. As such CONSTRAINT 6 would have to be used with extreme care.

A.3.3 Using SNOMED CT to document procedures as an ELEMENT-value

Record entries are also made to document activities. The relevant openEHR ENTRY subclasses are INSTRUCTION, ACTIVITY and ACTION. In the general sense, the following constraint is the most appropriate that can be offered as top-down guidance:

CONSTRAINT 7: Concepts in the descent of 71388002 | Procedure (procedure) can be used as ELEMENT-values where ELEMENT-value is not coded.

Given that, once captured in a record, there is no distinction for interpretation purposes between, for example, 165007007 | Allergy testing done (situation) and 252512005 | In vivo test of hypersensitivity (procedure), the following constraint should also be introduced:

CONSTRAINT 8: Concepts in the descent of 129125009 | Procedure with explicit context (situation) can be used as ELEMENT-values where ELEMENT-name is not coded.

From the published specification it would appear that different ENTRY subclasses are used depending on the state of the activity (planned, done etc.), so further refinement of this set is probably needed, along with detailed consideration of the interaction of certain Archetype constructs with SNOMED CT's procedure state representation.

A.3.4 For procedures – the use of a coded ELEMENT-name

It is probably fair to say that in general there may be less need to capture procedures in response to 'questions' above and beyond 'what procedure was performed', however there may be cases where such prompts would appear (e.g. the SNOMED CT code 1764920017 | Type of immunophenotypic analysis performed (observable entity)), and in order to support such circumstances it would seem reasonable to provide a further constraint comparable to CONSTRAINT 6, thus:

CONSTRAINT 9: Concepts in the descent of 363787002 | Observable entity (observable entity) OR 386053000 | Evaluation procedure (procedure) OR 108252007 | Laboratory procedure (procedure) can be used as ELEMENT-names where ELEMENT-value is coded from the value sets specified in CONSTRAINT 8.

As for CONSTRAINT 6, the caveat for CONSTRAINT 9 is that this is a valid combination provided the code in ELEMENT-name together with the code in ELEMENT-value does not yield a meaning that is substantially different from the meaning if ELEMENT-name was not coded.

A.3.5 Element association and containment

Whether by virtue of ELEMENT 'sibling' proximity (e.g. 'reaction severity' and 'specific substance' in the Adverse reaction Archetype) or by CLUSTER containment (e.g. the 'symptom' CLUSTER containing the 'location in body' or 'character' ELEMENTS in the 'symptom of pain' Archetype), SNOMED CT-coded statements in an Archetype are not independent from one another. There has been insufficient time in the project to date to explore the potential issues that this may cause, however a few facets are described here:

A.3.6 Primitive associations

Given the relatively unconstrained nature of new content additions to SNOMED CT (as well as its inherited content from its source terminologies), many clinical notions or nuances are primitively represented and not represented in any definitional model. By example (and with reference to the 'symptom of pain' Archetype), it would be possible to select a subtype of 22253000 | Pain (finding) that primitively represents a notion captured elsewhere in the relevant Archetype (e.g. 279093005 | Cramping pain (finding), where it is intended that 'cramping' is captured in one of the contained ELEMENTS ('character').

Strategies are therefore needed to avoid this risk of 'arbitrary representation', possibly requiring its explicit prohibition by the Archetype. This is a non-trivial design task and will require detailed evaluation of all value sets to exclude concepts whose primitive notions are preferentially represented elsewhere.

It is possible that some aspects of 'arbitrary representation' could be managed by the normalisation steps envisaged in the section '**Archetype transformation into 'SNOMED-conformant semantic units**' but these could not be relied on to iron out unmanaged 'arbitrariness' of data capture.

A.3.7 For findings, disorders and procedures – interaction with the SNOMED CT concept model

It was pointed out in the section '**Primitive associations**' that it is relatively easy to represent in the SNOMED CT code binding of one Archetype component notions that should be represented elsewhere in the Archetype, where those notions are primitively represented in SNOMED CT. It is not surprising therefore that the same problem is apparent for defined or potentially defined 'non-context' notions too. Once again with reference to the 'symptom of pain archetype', it is possible to represent the site and severity of a pain at both the level of the coded 'symptom of pain' CLUSTER and the contained 'location in body' and 'degree' ELEMENT.

Strategies are therefore needed to ensure the following where such duplication can occur:

(1) either duplication/redundancy is explicitly prohibited by the archetype (e.g. restricting the SNOMED CT 'symptom of pain'-level coding to either a single abstract 'pain' code or subtypes that do not mention nuances represented elsewhere)

(2) or duplicate/redundant representation is allowed, but conflicting records are avoided by dynamic value set bindings between COMPONENTS (e.g. if 'severe chest pain' is selected as the 'symptom of pain' then either appropriate values are selected for the contained 'location in body' and 'degree' ELEMENTS (based on reference data values), or these ELEMENTS carry null values to avoid duplication.

As a tentative constraint to make such associations explicit, and to extend the ELEMENT-name/value ranges appropriately the following is proposed:

CONSTRAINT 10: where a relevant RECORD COMPONENT can be explicitly referenced within an Archetype, suitable* Concepts in the descent of 410662002 | Concept model attribute (attribute) can be used as ELEMENT-names, and suitable* Concepts can then be specified (or further constrained). *'Suitable' here means as guided by the published SNOMED CT domain and range concept model.

By example, so long it is possible to identify (and make explicit relevant relationships) a suitable 'object COMPONENT' (e.g. 'the symptom of pain'), it should be possible to exploit the SNOMED CT concept model to provide an ELEMENT-name and ELEMENT-value set to represent the site of the pain (363698007 | Finding site (attribute) as the ELEMENT-name and concepts in the descent of 91722005 | Physical anatomical entity (body structure) OR 280115004 | Acquired body structure (body structure) as the ELEMENT-value).

Allow the use of attributes that are not part of the concept model should not be supported, and the use of concept model attributes as ELEMENT-names without identification of explicit links to named components (to allow reconstitution of an analysable SNOMED CT expression) should not be supported.

A.3.8 For findings, disorders and procedures – interaction with the SNOMED CT context model

Essentially a special case of 'Interaction with the concept model', interaction with the SNOMED CT context model is also possible. Once again with reference to the 'symptom of pain' Archetype, an ELEMENT is provided ('Currently present') to allow the capture of whether the pain symptom described is present or not. For purposes of comparable analysis it will be important to manage the overlap between this pattern and the potential to record similar notions within SNOMED CT directly. In the example case, it would be important either to prohibit the use of concepts in the descent of 81765008 | No pain (situation) (allowed by CONSTRAINT 2) as values for 'symptom of pain', or ensure that any ELEMENT-value/name pair mapping for 'currently present' is explicitly kept in step by a mechanism similar to that suggested in CONSTRAINT 11.

Essentially another form of containment, it is noted that amongst the example Archetypes are structures like 'Imaging request' (using the INSTRUCTION class) and 'Procedure undertaken' (using the ACTION class) and 'Past history' (COMPOSITION), all of which suggest that there are further complex interactions between SNOMED CT representations of procedure and finding states, temporal notions and subject of information/subject relationships to be investigated.

A.3.9 Identified terminology issues

A number of issues with SNOMED CT have been identified as part of this review exercise. The following list does not claim to be exhaustive, but is illustrative of a number of editorial/SNOMED-in-use issues that need to be resolved either within the globally published standard or locally for NHS purposes (the risk of local solutions being the hazards of non-interoperability with alternative local solutions developed elsewhere – e.g. for international record transfers or data comparison.

A.3.10 Inevitable missing primitives

It is fair to say that SNOMED CT will always be incomplete – there will always be significant primitive clinical notions that have not been added to the content in an anticipatory fashion. The practical upshot of this is for customers and producers of SNOMED CT need to develop realistic expectations on what needs to be captured in a coded form, and develop efficient, safe and implementable update mechanisms for novel content where rapid change requirements are identified.

A.3.11 Incomplete exploitation/incorporation of available content

Whilst neither exhaustive nor exclusively an issue of SNOMED CT/Archetype usage, there are a number of concept classes in SNOMED CT whose guidance for use is unclear at the moment. Notable examples are the following two categories:

Concepts in the descent of 272379006 Event (event)

Concepts in the descent of 48176007 | Social context (social concept)

In the former case many concepts which might in many ways be regarded as ‘clinical findings’ (or Archetype ‘Observations’) are found (e.g. ‘Accidental exposure to fertilizer (event)’), however it is not clear whether they are fully-interchangeable – notably whether the ‘findings context’ model (or something like it) can be invoked to say things like ‘definite accidental exposure to fertilizer’ or ‘no accidental exposure to fertilizer’.

In the latter case (and this is repeated in the section ‘**Incomplete input grammar…**’) there are several thousand ‘occupation’ codes. It is not clear from current guidance how these codes could be exploited, either for the straightforward recording of an occupation in a SNOMED CT-enabled system, or how they might be incorporated into expressions asserting that a particular occupation history might need consideration or be explicitly excluded in a patient assessment.

A.3.12 Content category errors

Qualitative assessment of SNOMED CT suggests that at the coarse-grained levels of top-level concept chapters (findings, procedures, substances…) or of concept ‘kinds’ (the bracketed tags on fully-specified names (e.g. body structure, morphological abnormality, cell…) its content is well categorised. It is however noticeable that when these categories (in particular concept ‘kinds’ are used to distinguish concepts for constraint specifications (e.g. ‘only use context-model negation for *disorder* concepts’)), it becomes apparent that the ‘kind’ tags are sometimes inconsistently applied. Such categorisation errors weaken the authority of ‘top down’ constraints such as those proposed above – requiring implementers (in this case Archetype developers) to use discretion and degrading the automation that can be used by implementers. By example, if it were agreed that a general razor for identifying

ELEMENT-values for EVALUATIONS was to select SNOMED CT ‘disorder’ concepts, then the set of Congenital gammaglobulinopathies would be incomplete, thus:

58034007 | Congenital hypergammaglobulinemia (disorder)

116133005 | Congenital agammaglobulinemia (disorder)

267460002 | Congenital hypogammaglobulinemia (finding) – this latter variant would have to be included by exception (and/or the data subsequently corrected) if such a high level distinction were made.

A.3.13 An 'incomplete' model

Essentially this is the (definitional) concept model equivalent of ‘inevitable missing primitives’. If SNOMED’s corpus of primitive notions is necessarily incomplete, it is likely also that there will always be aspects of legitimate concept combination that are also absent. The ‘Symptom of pain’ Archetype illustrates model incompleteness well; whilst the SNOMED CT model allows the formal representation of a pain’s site and severity, there are no attributes available for representing notions such as the aggravating factors or character of the same pain. As discussed above it is theoretically possible (by concept combination) to represent the combination of a pain character and relieving factor, this is not an approach that has previously been supported in NHS CFH guidance, not in the least because it is probably one of the harder forms of post-coordination to constrain consistently.

It should also be considered that some concept associations are not desirable to be represented within SNOMED CT. A relatively well-discussed example is the ‘causative’ association between statements (e.g. ‘disorder due to disorder’ or ‘disorder due to procedure’), where it is argued that an information model association may well be preferable. What is and is not included in the SNOMED CT concept model needs therefore to be a global design decision.

A.3.14 Incomplete input grammar and computable equivalence to 'meaning grammar'

‘Input grammar’ is used here to mean the terminology content to support ‘question and answer’ based content capture. SNOMED CT has three major concept classes that it is expected can currently ‘take a value’:

363787002 | Observable entity (observable entity)

386053000 | Evaluation procedure (procedure) [although this subsumes a lot of false positives for this pattern of use]

108252007 | Laboratory procedure (procedure)

The last of these (‘Laboratory procedure’) is probably out of scope for ‘input purposes’ (it is more likely to be used for the display of a laboratory test and its value, or to represent the test itself), but the other two classes provide the sort of concept that is likely to be used to represent a ‘question’, for example:

- ‘364373009 | Consistency of breast (observable entity)’ – what is the consistency of the breast?
- ‘225162003 | Examination of abdomen (procedure)’ – what was found on examination of the abdomen?

In both cases there is a risk that the answer is a long narrative response, but it is equally likely that the questions provoke simpler answers such as ‘normal’ or ‘soft’. In these cases it would seem reasonable to offer these nominal fragment responses to capture ELEMENT-name /-value pairs. However, two problems can be identified.

1. If we use the published value range for the SNOMED CT attribute ‘has interpretation’ as a guide for the content that can be used as a nominal or ordinal value for an observable entity, ‘normal’ is in scope but ‘soft’ is not. Additionally (and anecdotally) the finding 290063001 | Normal breast consistency (finding) is not modelled in a way that would allow equivalence detection.
2. ‘Evaluation procedures’ are not treated the same way as Observable entities (they cannot currently be the target of an ‘interprets’ attribute) so even if the appropriate response/value was ‘normal’ to the question ‘what was found on examination of the abdomen?’, equivalence could not be detected between this and the finding ‘163133003 | Abdomen examined - NAD (finding)’

A.3.15 An incompletely expressive grammar for value set specification

This issue has been discussed at some length in the TermInfo paper and will not be repeated here. Suffice it to say that current relational Subset/Reference set mechanisms are likely to be inadequate for value set specifications (in particular where post-coordinated Expressions are valid content – and further in particular those that invoke the finding and procedure context mechanisms). A broad requirement is for an expressive declarative grammar that supports various set theoretical associations, various hierarchical and ontological instructions, and supports cardinality constraints. One advantage of ‘decomposing’ SNOMED CT Expressions into the formalism of an Archetype is that it gives access to a standard notation for specifying cardinality constraints.

A.3.16 Specific instability of observables/measurement procedures

A topic of ongoing debate in SNOMED CT concept model and editorial circles is the best way to integrate fully ‘observable entity’ concepts and align them with other classes such as findings, measurement procedures and functions. Until a stable solution is agreed (and until the data is then modelled in alignment with this solution) there will be difficulties in the consistent and expressive use of such concepts.

A.3.17Incomplete solutions for negation/null/normality representation

These are probably not exclusively SNOMED CT issues – in particular for certain flavours of null such as 'it was not appropriate to ask this question of this patient group' – and none can be explored in detail here, but in brief:

SNOMED CT does not trivialise the complexities of negation, but at the moment has, within its formalism, only a partial mechanism for its expression. It has support for the simple case of saying that a 'disorder is not present' (e.g. 'no Asthma'), with machinery for detecting equivalence between both:

290000000|rash absent|

And

373572006|clinical finding absent|: 246090004|associated finding|=271807003|eruption|

However, since the logical structure of SNOMED CT organises negated concepts by the general subsuming the specific, even this case is complicated by a need for the reversal of subsumption rules in cases of negation. Also, until the reference data is fully modelled, the equivalence referred to above cannot be guaranteed. Finally, and hinting at a less clearly supported negation pattern, there is an incomplete division between 'disorder not present' and 'structure, function, process not present' (e.g. 'hand absent' or 'biceps reflex absent'). Treating these latter cases in the same way as 'no asthma' (1) does not work using the SNOMED CT mechanism for negation and (2) probably should not use this mechanism anyway as the nature of the negation is fundamentally different. There is therefore a need for SNOMED CT to supply consistent guidance on other patterns of negation, and to distinguish clearly which Concepts should invoke which negation mechanism.

Finally it is noted that many of the Archetypes reviewed introduce the distinct notion of 'normal observations'. Whether encouraging their capture as a distinct ELEMENT within a given Archetype could be debated here (does this preclude statements or normality being made elsewhere in the same Archetype?), but instead it is simply fair to point out the following. SNOMED has access to the following general pattern for formal (and extensible) representation of finding normality:

Normal property of system	**Interprets = property of system**	**Has interpretation = normal**
e.g.		
167990003 | Sputum appears normal (finding)	363714003 | Interprets (attribute) |= 277901007 | Sputum appearance (observable entity) |	363713009 | Has interpretation (attribute) |= 17621005 | Normal (qualifier value) |

However from the reference data it can be seen that only a fraction of findings with 'normal' in their termstring have the role 'has interpretation=normal' modelled, and that it is not immediately clear how this pattern of modelling/expression creation would always be carried out.

Appendix B: Pain symptom representation in *open*EHR

The following example is taken *open*EHR representation of pain symptoms using the archetype 'openEHR-EHR-CLUSTER.symptom.v2' as referenced in the presenting complain in the template 'Emergency-AbdominalPain.v2draft.oet' .

This example is used to illustrate in the body of the document.

node_id	Node			Terminology Binding comment
	Pain symptom [1]			<22253000 | pain |
at0001	Symptom [1]			
at0035	Nil significant [0..1] BOOLEAN			Could imply absent finding context if true.
at0034	Features [0..1]			
at0063	Date / time of onset [0..1] DATE_TIME			
at0002	Clinical description [0..1]			
at0113	Location [0..1]			
at0029	**Location in body [0..*]**			Probably same as **finding site** but multiple cardinality? 363698007 | finding site | = <91723000 | anatomical structure |
at0.117	**Radiating to [0..1]**			Not modelled in SNOMED CT but does have some specific pre-coordinated 'pain radiating to …' concepts. <9972008 | radiating pain |
at0046	Current intensity [0..1]			
at0047	**Degree [0..1]**			Maps reasonably well to **severity** 246112005 | severity | = <272141005 | severities |
at0022	0) not present	at0024	5) moderate	
at0044	1) trivial	at0025	8) severe	
at0023	2) mild	at0045	9) very severe	'**Current** intensity' may have implication for context model temporal context.
at0026.1	Pain score [0..1] INTEGER			
at0028	Duration [0..1] DURATION			
at0.119	Character [0..1]			
at0032	**Character [0..1]**			SNOMED CT does not model this but does have some pain concepts with these specific characters. These could be post-coordinated by conjunction.
at0.121	Crushing	at0.129	Superficial	
at0.122	Burning	at0.130	Throbbing	
at0.123	Cramping	at0.131	Sharp	
at0.124	Colicky	at0.132	Heavy	
at0.125	Deep	at0.133	Tearing	
at0.126	Diffuse	at0.134	Squeezing	'Superficial' and 'Deep' are in <301370002 | finding of sensory dimension of pain |
at0.127	Dull ache	at0.144	Stabbing	
at0.128	Shooting	at0.145	Griping	Most others are in <410720000 | pain by sensation quality |
at0.120	Description of character [0..1]			
at0115	Variation [0..1]			
at0003	**Variation [0..1]**			Not modelled as attributes of pain but pre-coordinated concept exist <<301369003 | finding of pattern of pain |
at0004	Constant	at0006	Fluctuating	
at0005	Intermittent			
at0116	Variation details [0..1]			

node_id	Node			Terminology Binding comment
at0033	Course [0..1]			
at0008	**Onset type [0..1]**			263502005 | clinical course | = 385315009 | sudden onset | OR 61751001 | gradual onset |
at0009	Gradual	at0010	Sudden	
at0060	Onset description [0..1]			
at0014	Precipitating factors [0..1]			
at0099	**Common precipitating factor [0..1]**			
at0100	exertion	at0101	cold weather	Not modelled but some specific pre-coordinated concepts exist.
at0103	medication change			
at0104	contact with known allergen			
at0102	recent infection			
at0015	Other precipitating factor [1..*]			
at0.135	Activity level at onset [0..1]			
at0.137	**Activity level [0..1]**			
at0.138	at rest	at0.140	during sleep	Not modelled
at0.139	lying flat	at0.141	on exertion	
at0.136	Activity level description [0..1]			
at0030	Date / time of maximum intensity [0..1] DATE_TIME			
at0016	Modification [0..1]			
at0018	Modifying factor [0..*]			
at0105	**Factor [0..1]**			
at0106	resting	at0109	eating	Not modelled
at0107	exercising	at0110	leaning forward	
at0108	breathing	at0111	lying flat	
at0019	Factor [0..*]			
at0064	**Change [0..1]**			
at0065	Resolved	at0067	No change	Not modelled
at0066	Better	at0068	Worse	
at0056	Change details [0..1]			
at0037	**Progression [0..1]**			
at0038	Resolved	at0042	No change	Not modelled.
at0040	Better	at0043	Worse	
at0011	**Cessation [0..1]**			Not modelled.
at0009	Gradual	at0010	Sudden	
at0114	Cessation description [0..1]			
at0058	Previous episodes [0..1]			
at0059	Any previous episodes [1] BOOLEAN			
at0090	Previous episode [0..*]			
at0.142	Date / time of previous episode [0..1] DATE_TIME			
at0057	Details [0..1]			
at0.143	Comparison [0..1]			
at0098	Number of previous episodes [0..1] INTEGER			
at0200	Other details [0..1]			