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HL7 CIMI Logical Model: Analysis Normal Form (ANF), Release 1

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Intended Audience

Analysis Normal Form (ANF) is intended for projects that aggregate clinical statements from a variety of sources, independent of formalism or approach used by the source system. The users of ANF—and subsequent implementation guidance—are developing applications that require determination if a clinical fact or situation was observed to exist or happen, and they wish to ensure that this determination is reliable and performed in accordance with the principles of patient safety and high-reliability organizations. These applications may include clinical decision support, reimbursement, public health reporting, outcomes research, and other types of data analysis.

The Learning EHR, 21st Century Cures, Patient-Centered Outcomes Research, and other US national, or international initiatives all examples of efforts that can benefit from ANF as they all depend on interoperable, reusable, and analysis-ready information that can improve outcomes, produce new therapies, and put into practice "precision medicine."

Abbreviated Glossary

ANF (Analysis Normal Form)	An approach to clinical statements that ensures the statement representation is reproducible and scalable, with the adherence to principles of being simple, reproducible, and use case driven, with immutability and no false dichotomies.
CDS (Clinical Decision Support)	A function for electronic health records systems designed to help sift through large amounts of electronic health data to suggest next steps for treatments, alert providers to available information they may not have seen, or catch potential problems, such as dangerous medication interaction.
CIMI (Clinical Information Modeling Initiative)	A workgroup of Health Level 7 (HL7) focused on improving the interoperability of healthcare systems through shared implementable clinical information models, and a sponsor of this whitepaper. For more information please see http://www.hl7.org/Special/Committees/cimi/index.cfm
FHIR (Fast Healthcare Interoperability Resource)	A HL7 interoperability specification for the exchange of healthcare information electronically
Normal Form	A defined standard structure for relational databases in which a relation may not be nested within another relation.
Solor	A project sponsored by the Department of Veterans Affairs that represents and brings together different terminology standards by using a single model that can encompass any customized content. Solor allows informaticists and developers to convert user-supplied terminologies into a single model using open source software to produce Solor content. For more information please see http://solor.io
Statement	A representation of a fact or situation was observed to exist or happen. See Also Clinical Statement, Statement Narrative.
Statement Narrative	A written account of a fact or situation was observed to exist or happen, corresponding to one or more statements. See Also Clinical Statement, Statement.
Input Forms (Structured Clinical Input Forms)	The manner by which clinicians author clinical statements and enter them into their organizations' electronic health record (EHR). Input forms have an impact as to how information is presented to the clinicians and how they enter the data, such as by constraining the information to allow only certain values to be entered, such as through a drop-down list or radio button, or breaking up large chunks of related information into smaller parts.

1. Why Analysis Normal Form? A Normal Form for Clinical Statements

A *clinical statement* is a definite and clear representation of a clinically-significant fact or situation that was observed to exist or happen. A clinical statement can be expressed as a *narrative* that provides a written account that can be naturally read by humans, as well as a *normal form* which is a machine-processable representation of the statement's data as a standardized and encoded fundamental form. Today, clinical statements are often represented in unpredictable and denormalized forms, which makes reliable and safe decision support challenging, and reduces the quality of other types of data processing.

Healthcare organizations are striving to become *high reliability organizations (HROs)*, characterized by high levels of safety under inherently risky, technologically-complex, and demanding conditions.[HRO_HIT] Deployment of EHR systems is nearly ubiquitous in the US and there is increasing opportunity to leverage standards-based clinical statements to improve population health through quality measures, case reporting, and decision support. The ability to measure and improve outcomes relies on consistent, high-quality data that was aggregated from a variety of systems. Analysis using normal form allows HROs to derive added knowledge from data and reach high levels and safety. [Chassin] A *standard* normal form can help replicate HROs across our industry.

In this document, we present background on other logical *HL7* and *ISO* clinical statement models, and focus on the need for—and logical specification of—an *Analysis Normal Form (ANF)*. ANF is a **normal form** intended to safely and reliably support data analysis that can be used to aggregate data created using any standard or non-standard input form or exchange mechanism. The ANF Reference Model, is a *logical model* and part of the *CIMI* library of models.

ANF is a model for clinical statements used in analysis that meet the following criteria: *Understandable, Reproducible, and Useful* (URU) [spackman][cimino]:

- ***Understandable***. The content of an *ANF statement* can be processed by health IT systems and understood by most healthcare providers, without reference to private or inaccessible information.
- ***Reproducible***. Multiple users or systems apply the ANF to the same situations and source data with the same/similar result.
- ***Useful*** (fit-for-purpose). The ANF statement has a practical value: analysis, research, outcomes, etc. that requires information aggregated across health IT systems.

This document describes how information systems can improve patient safety and outcomes by increasing the precision of clinical information using a normal form to enhance and support quality data and analysis.

1.1. Motivation: Why Do We Need ANF?

Information systems record and manage clinical statements using a variety of standard or ad-hoc models. However, both treatment and analysis of clinical statements require consistency not only at the format level (e.g. *CDA*, *FHIR*, V2) but also the content model (i.e. an instance of an *ISO/TS 13972* DCMs, CIMI model, etc.). [DCM_Quality] In most cases the data quality is the greatest obstacle to analysis, but even in the case of structured, semantically-clear information, inconsistency across sources of information raises obstacles to analysis and research. Analysis of aggregate information managed by health information networks poses the greatest challenge today because a meaningful use of data for patient outcomes or research requires a common format and level of semantic clarity.

Not only is there a potential for a lack of consistency with representing clinical statements with current *detailed clinical modeling* efforts, but there is also further variation in how the data is entered into information systems by end-users. This reality has a direct impact on patient safety if a clinical statement is recorded and displayed differently across the continuum of care. Clinicians author clinical statements and enter them into their organization's EHR systems as *"Structured Clinical Input Forms"* which we also refer to in this document as "input forms". This concept describes any data entry mechanism used by clinicians to record clinical statements. An instance of a clinical statement may be created using one or more input forms. Vendors compete on usability for seamless input forms but, in some cases, structured clinical statements are based on standards-based models (e.g. CIMI, openEHR archetypes) but they may also be based on proprietary models. For the purposes of this document, the type or usability of data structures used for capture or display of clinical statements is not in scope. We assume that **any suitably encoded** structured clinical statement may be suitable for normalization and analysis.

Therefore, clinical statements can be expressed and documented in many different ways in EHR systems, where input forms provide different options to document the same clinical statement. These differences pose challenges for how the data is modeled, how the data is stored, and therefore has implications on data retrieval, data analysis, accuracy of clinical analysis results.

1.1.1. Variation by Implementation: Structured Clinical Input Forms

Clinicians enter clinical statements into their organization's EHR typically in a manner that we call here structured clinical input form (or simply "input forms"), or the manner in which information is presented to the clinicians and how they enter the data, such as by constraining the information to allow only certain values to be entered - for instance, through a drop-down list, radio buttons, or breaking up large chunks of related information into smaller parts.

Let's consider the following example, represented below, in which data collected by an EHR combines information reported by devices with findings and interpretation:

1. A vital signs monitor transmits the systolic and diastolic blood pressure including date/time and the id of the device,

2. The nurse marks the measurement as "verified".

3. Next, the nurse documents how the measurement was performed:

   - using an adult cuff size
   - in prone position
   - brachial artery
   - on the left size
   - the micturition context is left empty/unknown/

4. Next, the physician adds an interpretation.

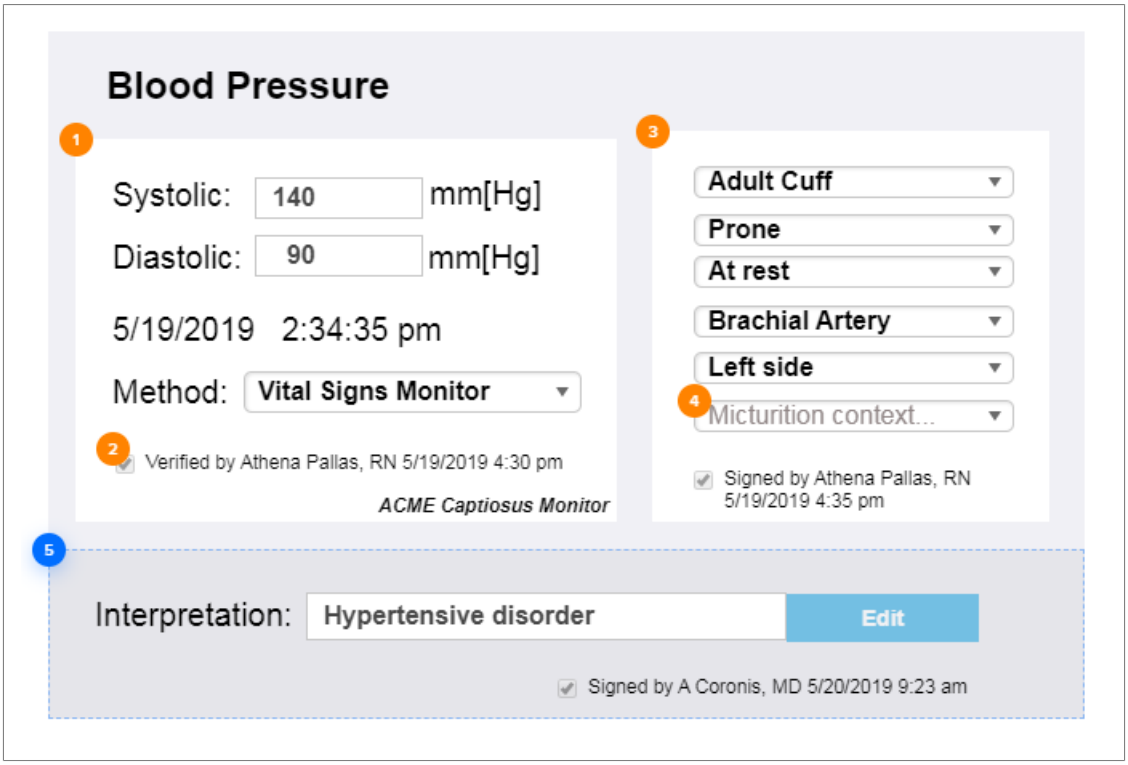


Figure 1.1. Blood Pressure Statement recorded by an EHR systems

Another EHR system may capture or display a subset of information about the blood pressure measurement - omitting "micturition context" and pre-coordinates site and laterality as:

- Right brachial artery
- Left brachial artery

The image below illustrates another distinct user interface for capturing a set of “clinical statements" related to Blood Pressure.

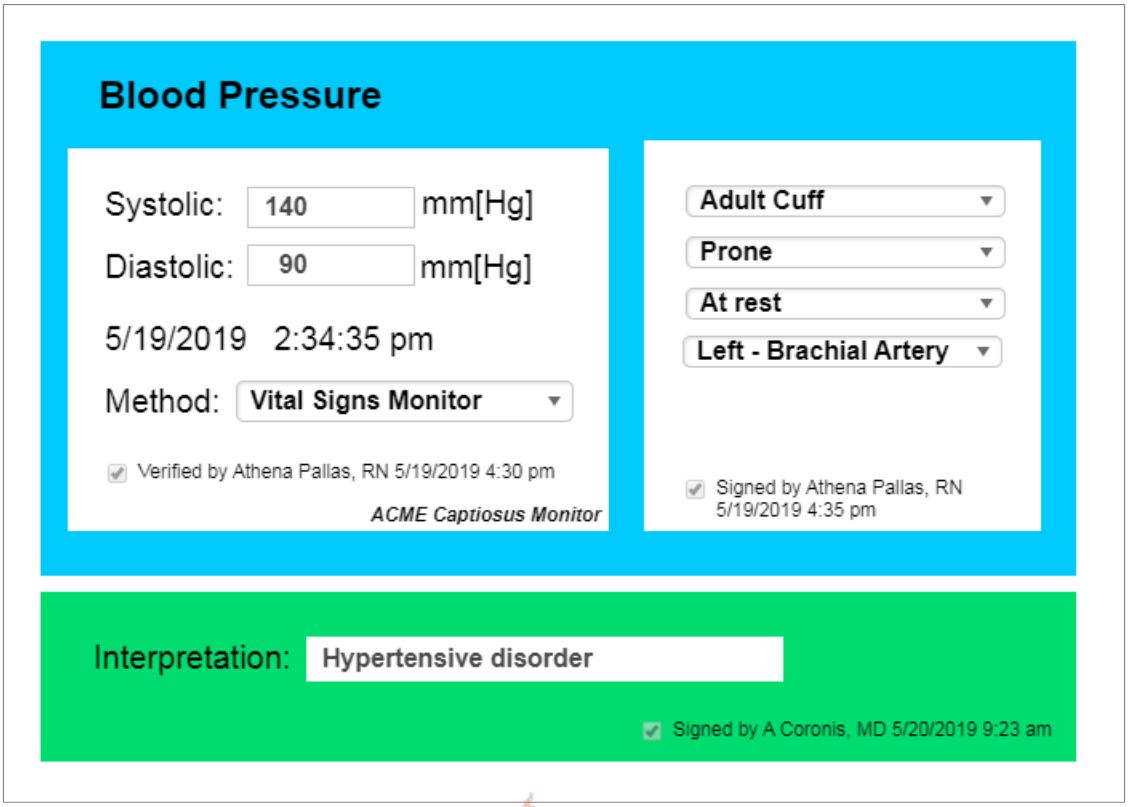


Figure 1.2. Alternative Blood Pressure representation in a second EHR system

In the first case, the structured clinical input form has separate drop-down constraints to enter the artery and laterality as distinct concepts. In the second wire frame, the structured clinical input form has combined the artery and laterality into a compound concept. This variation present in the structured clinical input forms may also have implications on how the clinical statement is modeled.

Ideally, clinical information is modeled in a manner that is most efficient for use. This is a problem because there are many different use cases for clinical information with a wide range of requirements. There is no single model that can be the most efficient model for all the various use cases. Maximum efficiency for each use case necessitates that any particular clinical information be available in multiple modeled forms. These models, although different in form, semantically represent the same information, and are known as *isosemantic models*. Any particular detailed clinical model exists within a family of isosemantic siblings.

1.2. Analysis Normal Form

Analysis Normal Form (ANF) is a logical model intended to represent a **normalized** view of aggregate clinical statements recorded during treatment for analysis, research, clinical decision support, and other purposes. ANF can be used to represent any isosemantic clinical statements irrespective of how the information was captured at its source (i.e. information systems or medical devices). ANF can be used in conjunction with other models intended to ensure that clinical information is structured and complete at the time of entry (e.g. CIMI models, ISO/TS 13972 Detailed Clinical Models) or exchanged among systems (e.g. HL7 CDA templates, *HL7 V2 message profiles*, *FHIR* profiles).

Clinicians, integrators, health IT developers, and researchers face different priorities, forcing trade-offs to be made that optimize data entry brevity at the cost of computability. ANF represents a collection of patterns and approaches to provide a predictable normal form to aggregate data sets across multiple systems . The more normalized a data set is, the simpler it will become to analyze, and errors will be

reduced. *Post-coordinated* compositional statements using ANF introduce the ability to faithfully expand from a reduced form or compare to other statements with ease and no loss of semantic integrity.

1.2.1. Objectives and Purpose of ANF

ANF's purpose is to introduce standards-based, normalized representation of clinical statements from a heterogeneous source using an objective quantitative ***measure*** to help evaluate the result, presence, and magnitude of a specific finding, request or observation. ANF requires an ability to classify the ***topic*** of a statement as standards-based and thus it depends on structured input form data that is encoded by formal terminology. ANF disambiguates input data along well-defined compositional layers (see Separation of Concerns). In practice, information systems may create normal data natively or transform other representations of clinical statements (e.g. C-CDA templates, FHIR profiles) to normal form (i.e., ANF).

Overall, ANF allows healthcare enterprises to normalize information aggregated across multiple sources to better support a set of analysis. ANF enhances the ability to:

- Specify clinical content extracted from EHR systems using FHIR
- Provide a common analysis form of data exchange, HL7 messages, FHIR and CDA
- Specify clinical content for User Interfaces
- Enhance information from clinical content for use in *Clinical Decision Support* Systems, Clinical Quality Measures and National Registries, Healthcare Guidelines and Protocols, and Epidemiological Research.

1.2.2. Assumptions for ANF

ANF provides a precise, consistent semantic data and terminology specification that is comparable and sharable between multiple care providers, health enterprises, and standards-based Healthcare Information Technology (HIT).

ANF supports highly post-coordinated compositional terminologies to provide greater content coverage than can be achieved by relying only on *pre-coordinated concepts.* Post-coordinated compositional terminologies are more expressive and can achieve better analysis than can be achieved by relying only on pre-coordinated concepts. ANF can help aggregate post-coordinated content in a normalized manner with respect to the content and semantics with the same representational structure as post-coordinated expressions used as input.

Successful analysis requires relatively high data quality that allows systems to define a precise topic, *category*, and clear measure or *result* of what was observed, requested, or assessed during treatment. ANF can be applied to any input data and any formalism as long as the data semantics and terminology are sufficiently precise to define the elements mandatory for analysis.

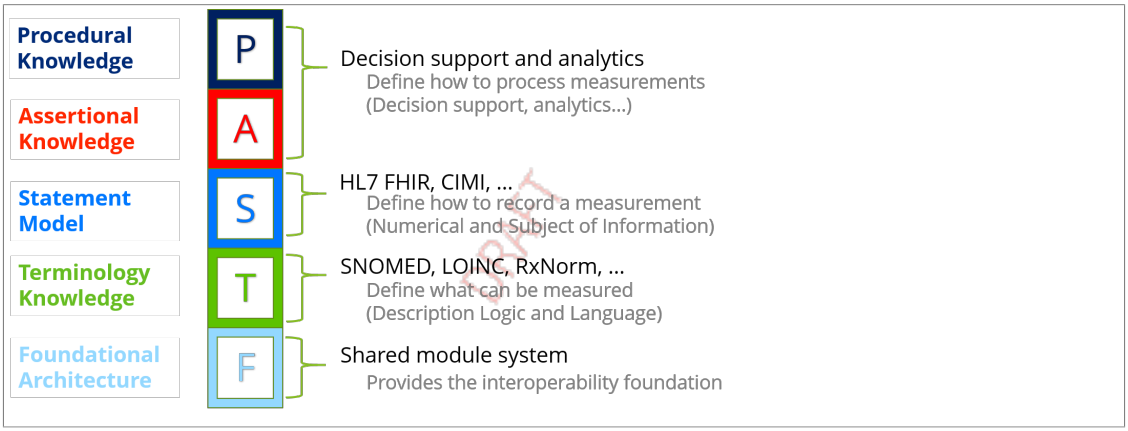
1.2.3. Approach - Architectural Separation of Concerns

Increased reliance on computerized health records, including Electronic Health Records Systems, requires standardized medical terminology to encode health information consistently across systems and enterprises. Clinicians require not only objective quantitative measurements (e.g. 90 beats per minute for a patient's pulse) but also contextual or procedural context (e.g. pulse oximetry, manual) about past observations or requests for future interventions. While two quantitative measurements may be the same, the procedural information could indicate meaningful semantic differences and lead to different clinical interpretation and treatment. As information is exchanged across systems, the solution requires a common understanding of data and a method to support knowledge-representation and clinical decision rules based on common

terminology and statements. Each component must address an aspect and, together they need to address the requirements of clinicians. Current HL7 standard implementations rely on profiles and templates to disambiguate statement and terminology, and provide sufficient precision for transactions, documents, and standards-based APIs. Therefore the architectural approach described here would be applicable to standards organizations developing interoperability-enterprise, and project-specific implementations in equal measure.

Functional decomposition across components or sections with a specific purpose is a foundational design principle for software design and complex system architecture: *Separation of Concerns* (SoC). It allows a complete system to be subdivided into distinct sections or components with well-defined functionality and dependencies. If successful, this approach allows individual sections to be able to be *reused*, as well as designed, implemented, and updated *independently* to address emerging *requirements*. This is especially useful and important in a medical context given how many different health information and clinical terminology projects are ongoing at any given time. Efforts are often uncoordinated and led by disparate and unrelated standards development organizations. In these cases, SoC allows teams to work independently, in coordination with each other, and reuse the resulting artifacts.

Figure 1.3, "Separation of Concerns: Knowledge Architecture" shows how a layered knowledge architecture can enable a separation of concerns.



Separation of concerns is an architectural design principle, whereby a system is divided into distinct sections, such that each section can address separate concerns. In this case, each architectural layer addresses separate concerns that can make use of the architecture layers below.

Figure 1.3. Separation of Concerns: Knowledge Architecture

Architectural Foundation – The *Architectural Foundation* of the Knowledge Architecture provides the common elements of interoperability such as object identity, versioning, modularity, and knowledge representation. It includes a) the foundation and building blocks of the common model; (b) how the repeatable transformation process of disparate standards into the common model promotes interoperability with other environments; and (c) how the modules of the architecture are tightly version controlled over time.

Terminology Knowledge – The Terminology Knowledge layer is responsible for structured sets of medical terms and codes that define concepts of interest, including descriptions, dialects, language, and semantic hierarchy. SNOMED CT, LOINC, and RxNorm are part of this layer

Statement Model – The Statement Model layer is responsible for defining how terminology concepts can be combined to create a statement. Within the data structures, additional detail to describe subject, numerical, and categorical information related to concepts can be added in this layer. ANF introduces a statement model specific to analysis and clinical decision support. Other standards-based clinical statements are discussed later in this chapter.

Assertional Knowledge – The Assertional Knowledge layer reuses information based on Statement Model. It is responsible for guidelines and business rules to assist clinical decision making. This includes facts and knowledge upon which concepts and combinations of concepts can assimilate into protocols. ANF statements can be used to support assertional artifacts.

Procedural Knowledge –The Procedural Knowledge Layer is responsible for information about standard ways to carry out specific procedures as well as other procedural guidelines, e.g. treatment protocols for diseases and order sets focused on particular patient situations. Procedural knowledge, together with assertional knowledge, enables clinical decision support, quality measurement, and supports patient safety. This layer is based on the interoperability infrastructure and terminology layers, incorporates the statement model for information retrieval, and uses the assertional layer to apply rules.

Examining a clinical procedure for controlling hypertension illustrates each of the layers of the informatics architectural separation of concerns.

- At the Terminology Knowledge layer, there may be various codes and terms from disparate source terminologies to define the a concept (e.g. hypertension). . Ideally, these overlapping codes and terms would be oriented to the same parent concept during the transformation and integration process at the Terminology layer (e.g., *Solor*).

- Moving to the Statement Model layer, blood pressure measurement values may be packaged as a numerical measurement (e.g., systolic BP = 140 mmHg) or the categorical data (e.g., pregnancy induced hypertension vs. renal hypertension) within a standard data structure to facilitate information exchange or retrieval, such as within a standards-based clinical statement (i.e. CIMI, CDA, FHIR, ANF, etc.).

- At the Assertional Knowledge layer, guidelines such as the recommendation to control hypertension to under 140/90 mmHg might be translated into a *clinical decision support rules* managed by Health Information Technology (HIT). If HIT is involved with programmed Clinical Decision Support, there may be additional rules to suggest hypertension medications (e.g., beta-blockers, ACE inhibitors) while also including rules to avoid medication contraindications.

- Finally, at the Procedural Knowledge layer, there may be a treatment protocol for different kinds of hypertension, including the considerations of, e.g. patient age, co-morbidities etc., which can be generated by an electronic clinical decision support system (Statement + Assertional layers). This layer adds to support for workflow and conditional logic (i.e. if-then-else).

A clear separation of concern enables the isosemantic transformation of standards-based clinical statements to normal form by decoupling structure from semantics and workflow in regard to an isosemantic representation in the Statement Model layer.

HL7 relies on implementation guides (for V2, CDA, and FHIR) to add sufficient terminology knowledge to standards-based clinical statements. Vocabulary constraints documented as profiles or templates are the mechanism to create interoperable implementation guides from health IT standards. Only after the Terminology Knowledge is fully defined, the standards-based statements can be used to support business and workflow decision points consistent with Assertional and Procedural layers described above.

1.3. Background: HL7 Clinical Statement Standards

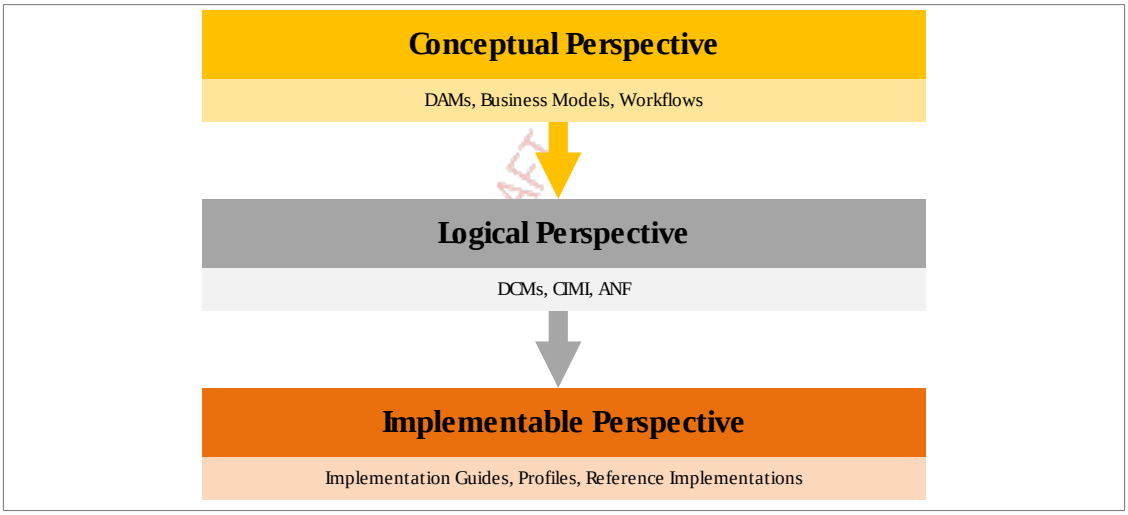
Clinical statement standardization has been a long-standing concern for HL7 and reuse of these content models across paradigms (e.g. messages, documents, services). Standardization has relied on model-driven approaches requiring a separation of concerns along with conceptual, logical, and implementation perspectives.

HL7 Service-Aware Interoperability Framework (SAIF) organizes HL7 standards along three perspectives (i.e. conceptual, logical, and implementable).

1.3.1. HL7 Service-Aware Interoperability Framework (SAIF)

To augment the HL7 Version 2 and Version 3 representations, HL7 introduced an architecture to allow for a clear separation of concerns among interoperability models and specifications from the abstract or conceptual to the most precise, implementable, and testable that ensures semantic interoperability. This architecture is the HL7 Service-Aware Interoperability Framework Canonical Definition (SAIF-CD). [SAIF-CD]

The SAIF-CD specification [SAIF-CD] defines three SAIF Perspectives: Conceptual, Logical, and Implementable. These perspectives are not formally equivalent with *Object Management Group's (OMG)* levels-of-abstraction in *Model-Driven Architecture (MDA)* even though it reuses the same derivation. Therefore, the Implementable Perspective is derived from the Logical Perspective and the Logical Perspective is derived from the Conceptual Perspective. This approach ensures that any implementable artifacts (i.e. service specifications, implementation guides) are traceable to business/clinical requirements and logical models of knowledge.



Like other CIMI models, ANF is a Logical Model that may be used to created implementation specifications.

HL7 Service-Aware Interoperability Framework: Canonical Definition Specification, Release 2

Figure 1.4. Model Derivation based on SAIF-CD

However, the SAIF Conceptual Perspective is not completely equivalent to the MDA concept of *Computationally Independent Model (CIM)*, the Logical Perspective is not equivalent to the MDA *Platform Independent Model (PIM)*, nor is the Implementable Perspective equivalent to the MDA *Platform Specific Model* although this Perspective is the SAIF Perspective that most closely aligns with an MDA analogue.

1.3.1.1. Conceptual Perspective

These artifacts are most commonly focused on the "Problem-Space" rather than the "Solution Space," and contain explicit, unambiguous descriptions of the various dimensions of the component (e.g. clinical statement) or system being specified.

A fully-specified Conceptual Perspective thus should be both readable and traceable by Domain Experts and Subject Matter Experts and rigorous enough to serve as input into the development in the Logical Perspective.

In HL7, the Conceptual Perspective is represented by *Domain Analysis Models (DAMs)*and business models that represent stakeholder requirements analyzed by *SMEs* and *DEs*. This perspective that precede the development of either logical or implementable artifacts and it is key to successful testing of implementations.

1.3.1.2. Logical Perspective

Artifacts in the Logical Perspective represent traceable translations of Conceptual-level artifacts into a form and format, usable by and useful to architects and "inward-facing analysts." Also included are additional specification materials required by architects preparing artifacts for consumption by developers.

There are no definite boundaries between the Logical and Implementable Perspectives. Therefore, it is important for organizations such as HL7 to standardize logical models used to generate/create implementable artifacts (i.e. implementation guides, profiles, and templates). *CIMI Clinical Statements* , ISO/TS 13972 Detailed Clinical Models, and ANF statements all belong in this perspective.

1.3.1.3. Implementable Perspective

Artifacts in the Implementable Perspective are typically defined by developers or standards implementers, often through discussion with software designers, architects, or system integrators. Note that the artifacts in the Implementable Perspective are not actual implementations, but rather implementable in a number of implementation instances. Thus, all the necessary technical bindings, including data types, value sets, class libraries, and interface specifications are part of the Implementable Perspective. FHIR implementation requires a combination of profiles and test cases to ensure that implementations meet the requirements used to derive the conceptual and logical models.

1.3.2. HL7 Version 3 Clinical Statement

Starting with *HL7 Version 3* [HL7v3], the minimum requirements for the interoperable clinical statement:

> *"Clinical Statement for the care of patients (persons, animals and other entities) is:*
>
> *An expression of a discrete item of clinical, clinically-related or public health information that is recorded because of its relevance to the care of a patient or other entities. Clinical or public health information can be expressed with different levels of granularity and therefore the extent and detail conveyed in a single statement may vary. To be regarded as a Clinical Statement, a concept must be associated with a patient or other entity in a manner which makes clear:*
>
> - *Its temporal context*
> - *Its relationship to the entity or entities*
>
> *In the case of an observation, its mood and presence, absence or value*
>
> *In the case of a procedure, its mood and status*
>
> *This clarity may be achieved by:*
>
> - *Explicit representation; or,*
> - *Implicit application of defaults ONLY where explicitly modeled rules state the appropriate defaults."*

HL7 Version 3 Standard: Clinical Statement CMETs Release 10

Table 1.1. HL7 V3 Clinical Statement Definition

The V3 Clinical Statement Model is applied across CDA implementation guides including the US-Realm Consolidated CDA (C-CDA) to represent CDA document entries. A V3 Clinical Statement Model is a *polymorphic model*: it can represent observations, procedures, encounters, public health reports, supply, medications, exposure, and derivations of clinical acts. The C3 Clinical Statement model provides a Statement Model with partial Terminology constraints. For example, Clinical Statements in a CDA document section need to be constrained to add the precision needed to support the Terminology Knowledge layer. CDA entry and sub-entry templates can be used to create precise implementations of theV3 Clinical Statement model for a specific type of clinical statement (e.g. Procedure Activity, Problem Observation) sharing a common statement model but different terminology and usage constraints. The US-Realm C-CDA specification consists of a set of templates that constrain the document, sections, and entries used in each section.

1.3.3. CIMI Statements

The *Clinical Information Modeling Initiative (CIMI)* is defining a library of logical *clinical information models* using a common modeling formalism. CIMI intends to improve the interoperability of healthcare information systems through shared detailed clinical information models that can be used to generate platform-specific model specifications such as FHIR profiles, CDA templates, OpenEHR Archetypes, ISO 13606 Archetypes, ISO/TS 13972 DCMs, CIMI models are grouped into semantically equivalent (or 'isosemantic') families of detailed clinical models, which capture the same clinical meaning using different combinations of pre and *post-coordinated concepts* and corresponding information model structure. The central focus of the CIMI Reference Model is the CIMI Clinical Statement. A CIMI Clinical Statement represents structured electronic communication made about a patient typically documented as an 'entry' in the patient record.

Unlike the V3 Clinical Statement Model applied in C-CDA, CIMI models are designed with Terminology Knowledge and provides a separate model for each type statements, organized into a comprehensive library.

CIMI clinical statements are further explained in this document (See Current CIMI Modeling Efforts).

1.4. About this Document

This document describes how information systems can improve patient safety and outcomes by increasing the precision of clinical information using a normal form to enhance and support quality data and analysis. In the subsequent chapter we will provide a deep dive into the building blocks and constructs for ANF, in a chapter containing the ANF Reference Model and illustrative examples of ANF modeling.

Subsequently, we will outline how the various building blocks and attributes work together to create ANF Clinical Statements. We then provide the ANF Modeling Methodology, including a list of modeling principles and rules. Next, we discuss how clinical statements can be transformed and normalized into ANF Clinical Statements. Finally, we discuss the implications of ANF on data quality, clinical decision support, and ultimately, patient safety and outcomes. In the appendices, we explore current CIMI modeling efforts including illustrative examples for modeling CIMI clinical statements. We also compare and contrast ANF Clinical Statements and CIMI Clinical Statements in an appendix.

Note

Throughout this document, SNOMED CT is used to describe clinical concepts and illustrate sample statements based on both ANF and CIMI logical models.

2. Building Blocks: ANF Reference Model

The *ANF* Reference Model is a logical information model describing the format of a normalized clinical statement that may have originated from an information system data store, a standard-based message (e.g. HL7 Version 2), a standard-document (e.g. *HL7 CDA*), or a standard-based resource (e.g. *HL7 FHIR*), or an instance of a *CIMI model* (e.g. FHIR-based profile, *openEHR* archetype) .

2.1. ANF UML Model

The ***ANF Reference Model*** is a logical model and uses *Object Management Group (OMG)* *Unified Modeling Language (UML)* 2.0 notation to describe the structure of normalized *clinical statements* for computational analysis. This *logical model* may be implemented using any programming language, database technology, or interoperability specification (e.g. FHIR) suitable for analysis. ANF is intended to normalize approaches and methodologies in use across the industry and provide a uniform representation of data to enable analysis.

The following diagram describes the logical structure of a clinical statement that conforms to the Analysis Normal Form specification. At a high-level an *ANF statement* defines the topic (**WHAT** happened, was observed, requested, measured, asserted, etc.) and under what circumstances-(**HOW**, **WHY, WHEN, and with what RESULT**).

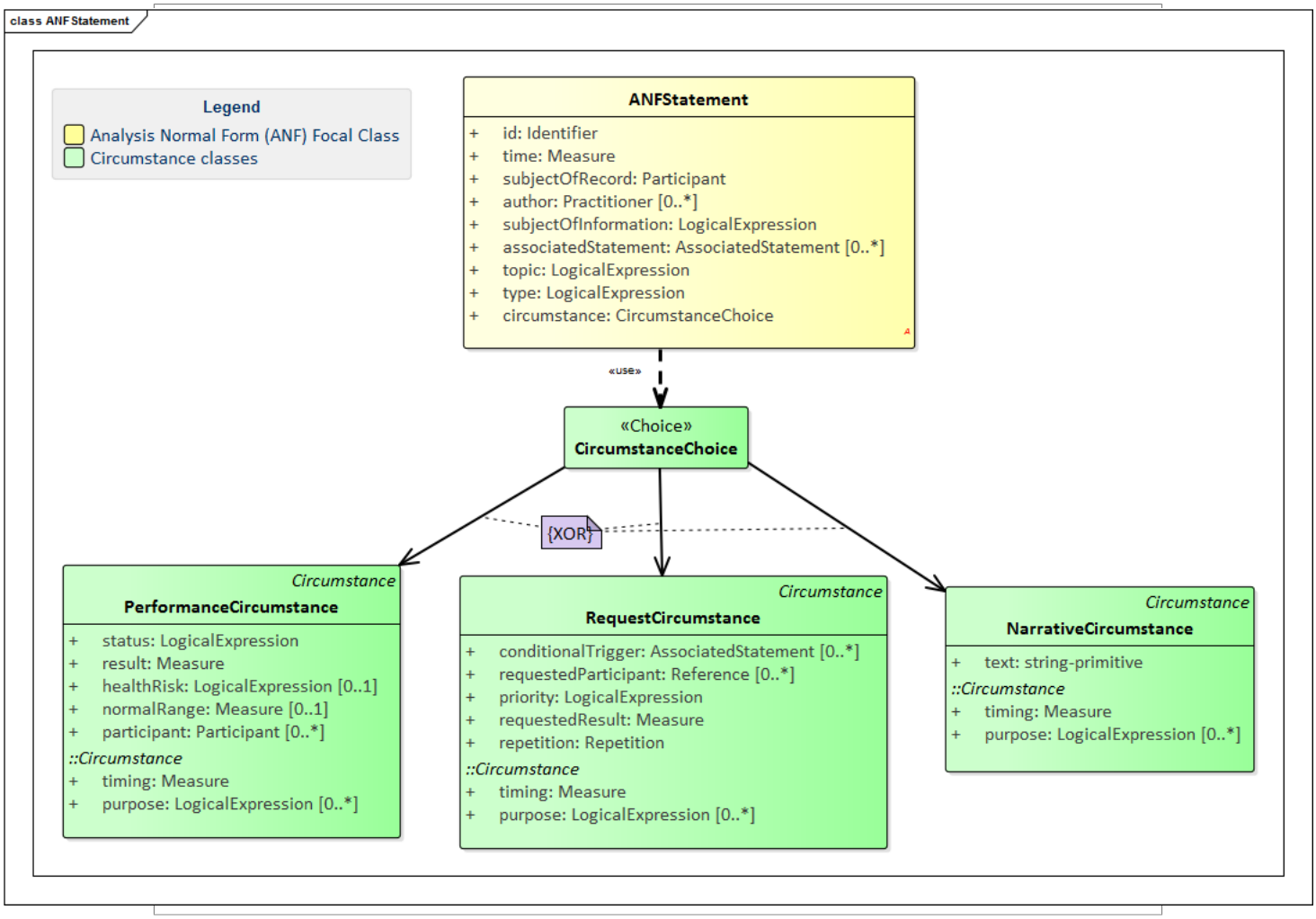


Figure 2.1. ANFStatement Structure

2.1.1. ANFStatement

This is the main class which describes a clinical statement. Most importantly it contains the '**topic**' which describes what this statement is about, and the '**circumstance**' which will contain either request or result information regarding the '**topic**'.

Attribute	Multiplicity	Notes
id Identifier	[1...1]	Unique Identifier of the statement.
time Measure	[1...1]	This data element describes when the statement was documented. Is its expressed as a **Measure**. For example the date of **2019-07-09T00:12:31+00:00** would be represented as Unix Epoch time as **1562631151** seconds : • interval.lowerBound = 1562631151 • interval.includeLowerBound = true • interval.upperBound = 1562631151

Attribute	Multiplicity	Notes
		• interval.includeLowerBound = true • semantic = Seconds | 257997001 The ANFStatement separates the timing related to documenting a statement vs, the timing of the phenomenon that the statement is describing. This data element specifies when the statement was recorded/asserted.
subjectOfRecord Participant	[1...1]	A patient's clinical record will contain many statements. The subjectOfRecord is a reference to the patient clinical record in which this statement is contained.
author Practitioner	[0...*]	Optional reference(s) list of identified authoring practitioners.
subjectOfInformation LogicalExpression	[1...1]	A logical expression describing the subject of the statement; it's used to express **WHO** the clinical statement is about. A patient's clinical record may contain statements not only about the patient, but also statements about children, relatives and donors. Thus, some possible values for subjectOfInformation, would include codes for 'subject of record' (the patient), 'family member', or 'donor'. The majority of statements will have a subjectOfInformation with a value of 'subject of record', since most statements in a patient record will be about the patient. The subjectOfInformation is used to represent who the statement is about. This is normally the patient unless explicitly stated otherwise.
associatedStatement AssociatedStatement	[0...*]	An ANF statement to the performance of an action. If the topic is a laboratory result panel, each association would point to another statement which is a laboratory result. It may include: • a precondition • an interpretation
topic LogicalExpression	[1...1]	This data element is an expression of **WHAT** is being requested or what was performed. For both ANFStatement types (request or performance) a *pre-coordinated* or *post-coordinated* “procedure” concept as a logical expression is required to sufficiently capture the action, which is either requested or performed. The topic is the central component of clinical statements. The following are proposed principles for the topic of an ANFStatement.

Attribute	Multiplicity	Notes
		Principle 1: The topic defines the action (being performed or requested) or what is being requested, measured or observed. **Principle 2:** The topic has to be able to exist on its own and still retain original intent and clarity of meaning. **Principle 3:** Each clinical statement may only have one topic [but the topic is comprehensive expression].
type LogicalExpression	[1...1]	This data element distinguishes between a performance (**'performed'**) and a request (**'requested'**). Performances may be observational performances, e.g. the observation of a clinical finding or disorder being present or absent. They can also be a procedure or intervention which has been performed on the subject of record in the past, e.g. “a procedure using a 12-lead electrocardiogram”. Performances can – but do not have to – include quantitative or qualitative results, e.g. “3 dot blot hemorrhages” or “Hepatitis A antibody positive”.
circumstance CircumstanceChoice	[1...1]	A choice of circumstance appropriate to the type of clinical statement.

2.1.2. Circumstance

Circumstances can describe **HOW**, **WHY, WHEN, and with what RESULT** a requested or performed action will be or was carried out. ANF promotes a normalized representation of observation or intervention results where all results are reduced to a "measure". This approach reduces data retrieval difficulties by eliminating the potential for multiple differing representations of the same clinical statement. For example, with coded results there are multiple potential methods to represent eye color that complicate data retrieval. The Topic could be a Finding refined by an Observable (Iris finding->Interprets = Color of iris) or a Finding with no refinement (Finding of color of iris). In both of these cases the Result would be a qualifier of Blue color. The ANF Statement would represent Eye color using the Blue iris Finding as the Topic and the Result would be Present, represented as interval.lowerBound =1, interval.upperBound=INF.

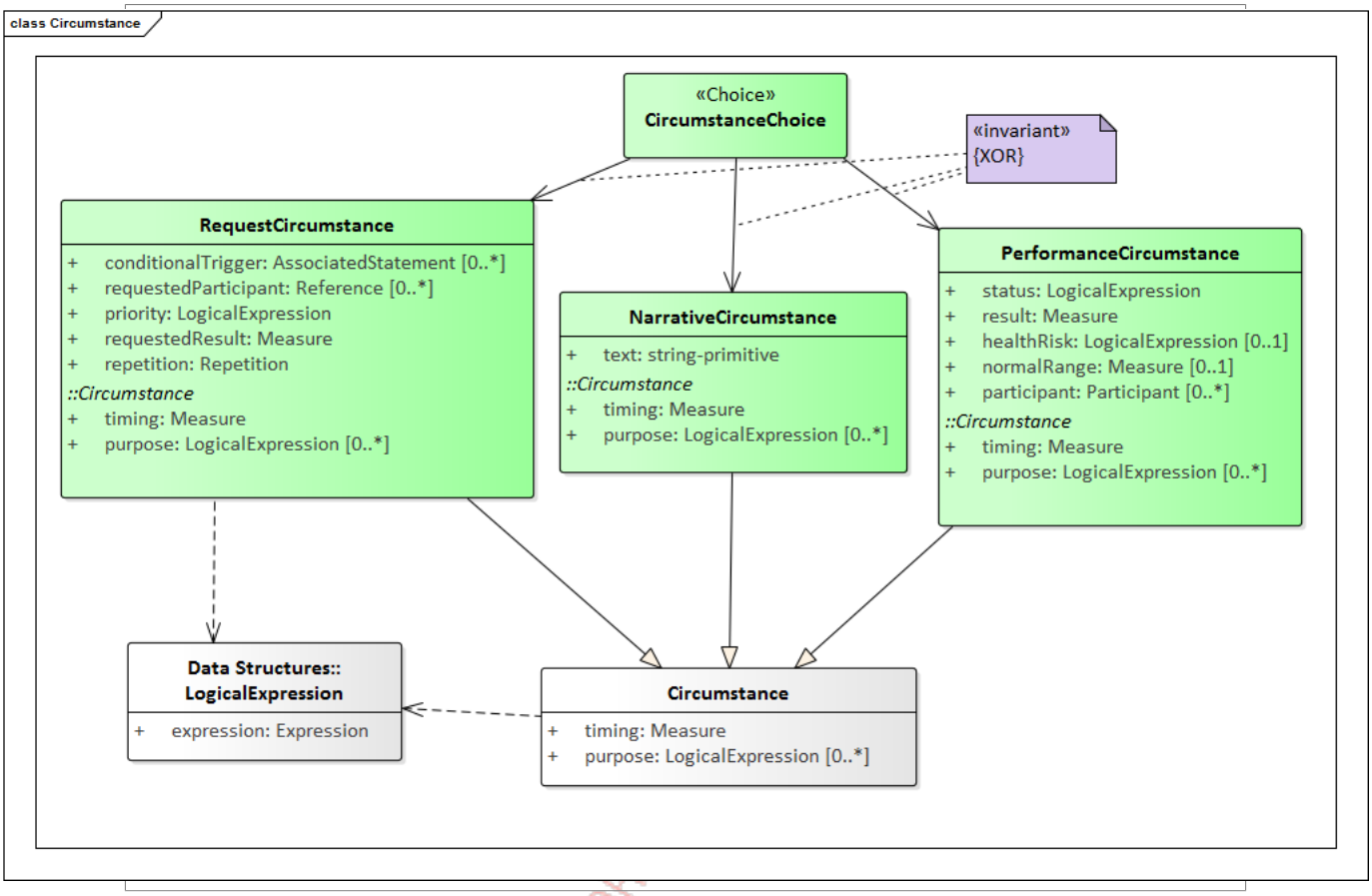


Figure 2.2. Circumstance

2.1.2.1. CircumstanceChoice

This class provides a exclusive choice of circumstances that may chosen when an ANFStatement is instantiated:

- PerformanceCircumstance
- RequestCircumstance
- NarrativeCircumstance

2.1.2.2. Circumstance

This abstract class is used to describe the default data needed describe any circumstances associated with a clinical statement.

Attribute	Multiplicity	Notes
timing Measure	[1...1]	**WHEN** a requested action should be performed or **WHEN** an observed finding or disorder was present or absent. Timing is used to capture a time or time range for • Requests for action at a future time

Attribute	Multiplicity	Notes
		• Performance of action, which has taken place in the past (including “History of X….) • Performance of action that hasn't taken place
purpose LogicalExpression	[0...*]	This data element describes WHY a procedure was requested or performed in a post-coordinated expression, based on two possible procedures: • 386053000 |Evaluation procedure (procedure)| • 277132007 |Therapeutic procedure (procedure)| The procedure is then refined by post-coordinating with a “363702006 |Has focus (attribute) |” attribute and identifying a finding/disorder or procedure concept as the value for the attribute.

2.1.2.3. RequestCircumstance

This class further specifies **HOW** a requested action is to be performed, e.g. how often or how long.

A Request for Action clinical statement describes a request made by a clinician. Most of the times, but not always, the object of the request (e.g., lab test, medication order) will be fulfilled by someone other than the clinician (e.g., lab technician, pharmacist) making the request. All information about the request will be documented in this clinical statement, including information about details relating to the request, such as patient must fast for 12 hours before having a lipids blood test.

Examples:

- Request for Rheumatoid factor 1 time routine
- Request for X-ray chest to evaluate for heart failure
- Cardiology referral
- Ribavirin 200 mg capsule oral, take 2 capsules every morning
- Advised to participate in tobacco cessation counseling once a week.

Attribute	Multiplicity	Notes
conditionalTrigger AssociatedStatement	[0...*]	This data element is used to represent a condition, or set of conditions that must exist in order for Request to be executed. For example, Ibuprofen 400 mg tablet oral every 6 hours as needed for pain, the use of Ibuprofen is conditional on the presence of back pain.
requestedParticipant Reference	[0...*]	This data element is an optional list of either specific persons or roles who perform an action, assist in performing an action or are targets of an action.
priority LogicalExpression	[1...1]	This data element species the priority with which a requested action has to be carried out, e.g. “routine” or “stat”. By default a Request will be considered "routine" unless otherwise specified.

Attribute	Multiplicity	Notes
requestedResult Measure	[1...1]	This data element specifies the measurable result.
repetition Repetition	[1...1]	This data element describes when an action is requested for more than a single occurrence using the Measure data structure: • When the repeated action should begin (periodStart), e.g. NOW • How long the repetitions should persist (periodDuration), e.g. for 3 weeks • How often the action should occur (eventFrequency), e.g. 3 times per week • How long between actions (eventSeparation), e.g. for 2 weeks • How long every action should last (eventDuration), e.g. for 5 minutes

2.1.2.4. PerformanceCircumstance

This class describes the circumstances associated with a statement. It is used when an action or observation are performed and specifies the result of intervention using both as a measure and a coded status.

For example, "*Insulin placed on hold 24 hours prior to catheterization*" would have a status of "*On hold*". A typical, successfully completed procedure would have a status of "*Completed*".

Attribute	Multiplicity	Notes
status LogicalExpression	[1...1]	This is a coded value representing the current status of the intervention.
result Measure	[1...1]	Intervention result as a measure.
healthRisk LogicalExpression	[0...1]	This optional data element is used to flag a result with coded values such as 'low', 'normal', high', and 'critical'.
normalRange Measure	[0...1]	This optional data element is the interval of values that are normal for the observation/finding described by the "topic" for this "subject". It refers to "normal" for the patient/subject with these conditions.
participant Participant	[0...*]	This optional data element identifies the practitioner(s) responsible for the results reported.

2.1.2.5. NarrativeCircumstance

This class is used to describe the circumstances of a clinical statement using natural language/text rather than a structure.

This class may be used to specify either a performance or request circumstance.

	Multiplicity	Notes
text string-primitive	[1...1]	Text description of circumstances.

	Multiplicity	Notes

2.1.3. Data Structures

The following are data structures used to represent an ANFStatement. This section describes the data structures specific to ANF. This model references a set of logical structures to represent unique identifiers (i.e. Identifier, Expression) and primitive types (boolean, float).

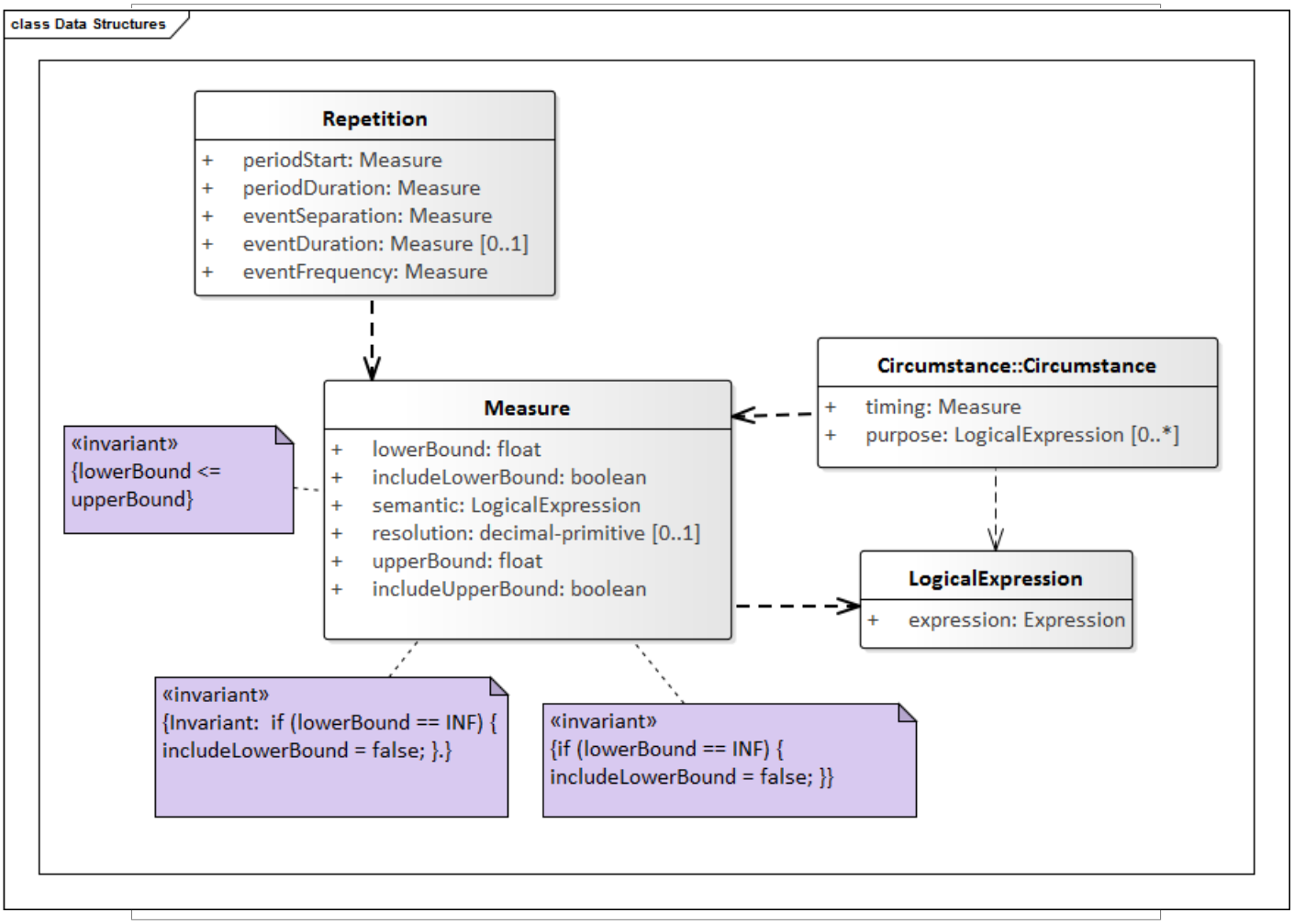


Figure 2.3. Data Structures

2.1.3.1. Measure

This class captures measurable elements of clinical statements , e.g. the results of test procedures, time periods, frequencies of repetitions for procedures or medication administrations. The measure formally represents a numeric interval between two nonnegative real numbers with a semantic and precision/resolution. The interval can be open or closed depending on whether the upper and lower bounds are included in the measure interval.

The measure provides a single way to represent both “presence” or "absence" values and numeric values for a phenomenon. In general,the interval value represents the numeric range within which the observed value of a phenomenon occurs. Note that this formalism allows both exact values and ranges of values to

be expressed. In case that the beginning and end point of an interval are the same value, the meaning is that the value of the phenomenon is exactly that value.

In the case that the lower and upper bound of an measure are the same number, ***n***, the meaning is that the value of the phenomenon is exactly ***n***.

- [5,5] : exactly 5 ; [0,0] : exactly 0

In the special case that the beginning of the interval is a number, n, and the end point is INF (infinity), the meaning is that the value of the phenomenon is > n or >=n, depending on whether the interval is open or closed.

- (0,INF) : > 0 ; [10,INF) : >= 10

The interval value also represents whether a phenomenon is “present”, “absent”, or “indeterminate”. Specifically, any interval value that includes only numbers that are > 0 also denotes the value “present”.

Any interval value that includes only the number 0, itself, denotes the value “absent”. Any interval value that includes both the number 0 and at least one number > 0 denotes the value “indeterminate”. Lastly, there are two interval values that explicitly denote “present” and “absent,” respectively. These value may be assigned to phenomena that would not otherwise take on a numeric value (such as “nausea”):

- Nausea value = [0,INF) : present
- Nausea value = [0,0] : absent

Attribute	Multiplicity	Notes
lowerBound float	[1...1]	It specifies the lower bound of a measurable element. This can be the lower bound of a range: • For the “Tumor greater than 1 cm but less than 4 cm” the lower bound is 1. • For a test result, which is not a range, lower and upper bound are the same. Example: systolic blood pressure 110 mmHg. The lower and upper bound are both 110 mmHg.
includeLowerBound boolean	[1...1]	It states whether the lower bound in the interval is included in the interval. In the tumor size example above, the lower bound would not be included. The lower range size of 1cm is not included. The inclusion or exclusion of lower bound is needed to express measurable elements which include relative properties, such as “greater than”, “less than” and others. Example: “Persistent cough for more than 10 days”. If a lower bound of “10” is chosen, it would not be included, because the example states: more than 10 days. Choosing “11” would require to include the lower bound If "true" the lower bound is part of the interval. **Invariant**: if (upperBound == INF) { includeUpperBound = false }.
semantic LogicalExpression	[1...1]	Measure semantic represents a unit of measure or scale specified by the interval values. It is described using a logical

Attribute	Multiplicity	Notes
		expression using standard-based terminology (i.e. SNOMED CT). For systolic blood pressure, the unit of measure is millimeters of mercury, and thus the measure semantic is a SNOMED CT concept: 259018001 |Millimeter of mercury (qualifier value). For blood glucose measurement daily for 2 weeks, the measure semantic would be “258705008 |week (qualifier value)”. For quantity/count measure values, the measure semantic to express a number of findings or phenomena described in the ANFStatement.topic "3 dot-and-blot hemorrhages " would be "30766002 | Quantitative". If Measure is used to represent date or time: • Date/time using Unix Epoch time: [762636008] Duration, [257997001] Seconds • Duration using Unix Epoch time start time and end time: [762636008] Duration, [257997001] Seconds
resolution decimal-primitive	[0...1]	It defines the possible or allowed increments in which the measured “thing” can be counted. In the example of the systolic blood pressure of 120 mmHg, the resolution is “1”, because the blood pressure measurement result can be counted in 1 mmHg increments. The Resolution is not always defined or known. Example: a clinical statement like “History of breast cancer” implies an undefined amount of time in the past and it is not stated, if it is years, months, etc.
upperBound float	[1...1]	It represents the upper bound of a measurable element. This can be the upper boundary of a range: For the “Tumor greater than 1 cm but less than 4 cm” the upper bound is 4. In cases, where the measurable element does not represent a range, upper and lower bound have the same value. **Invariant**: it must be greater than or equal to the lower bound.
includeUpperBound boolean	[1...1]	It states whether the upper bound in the interval is included in the interval. Similar to lower bound, where the measurable element has relative properties, the same rules apply. If the upper bound of a measure is not defined, e.g. “blood glucose measurement daily for at least 2 weeks”, the upper bound will be captured as “inf” (infinite). Infinite as an upper bound is never included. If "true" the upper bound is part of the interval. **Invariant**: if (lowerBound == INF) { includeLowerBound = false }.

2.1.3.2. Repetition

This class builds on Measure and it is used to represent when an action is requested for more than a single occurrence. Repetition is an optional component for a RequestCircumstance.

Attribute	Multiplicity	Notes
periodStart Measure	[1...1]	This required field is used to represent when a repeated action should begin (e.g. NOW). If it is not specified, a default value of [0,INF) will be used.
periodDuration Measure	[1...1]	This required field is used to represent how long a repeated action should persist (e.g. for a year). If it is not specified, a default value of [0,INF) will be used.
eventSeparation Measure	[1...1]	This required field is used to represent how long between actions (e.g. 1 week). If it is not specified, a default value of [0,INF) will be used.
eventDuration Measure	[0...1]	This optional field is used to represent how long a repetition should persist (e.g. for 2 hours). If it is not specified, a default value of [0,INF) will be used.
eventFrequency Measure	[1...1]	This required field is used to represent how often the action should occur (e.g. 4 times per month). If it is not specified, a default value of [0, INF) will be used.

2.1.3.3. LogicalExpression

This class represents is a wrapper for logical expression.

Attribute	Multiplicity	Notes
expression Expression	[1...1]	Logical expression could be represented using FHIR Expression structure or a similar standard-based syntax ((e.g. *SNOMED CT Expression Constrain Language - ECL*). The expression must use valid, standard-based terminology.

2.1.4. References

A clinical statement references other information managed by a system:

- references to patient/records
- references to health practitioners

ANF statements may also reference other related statements

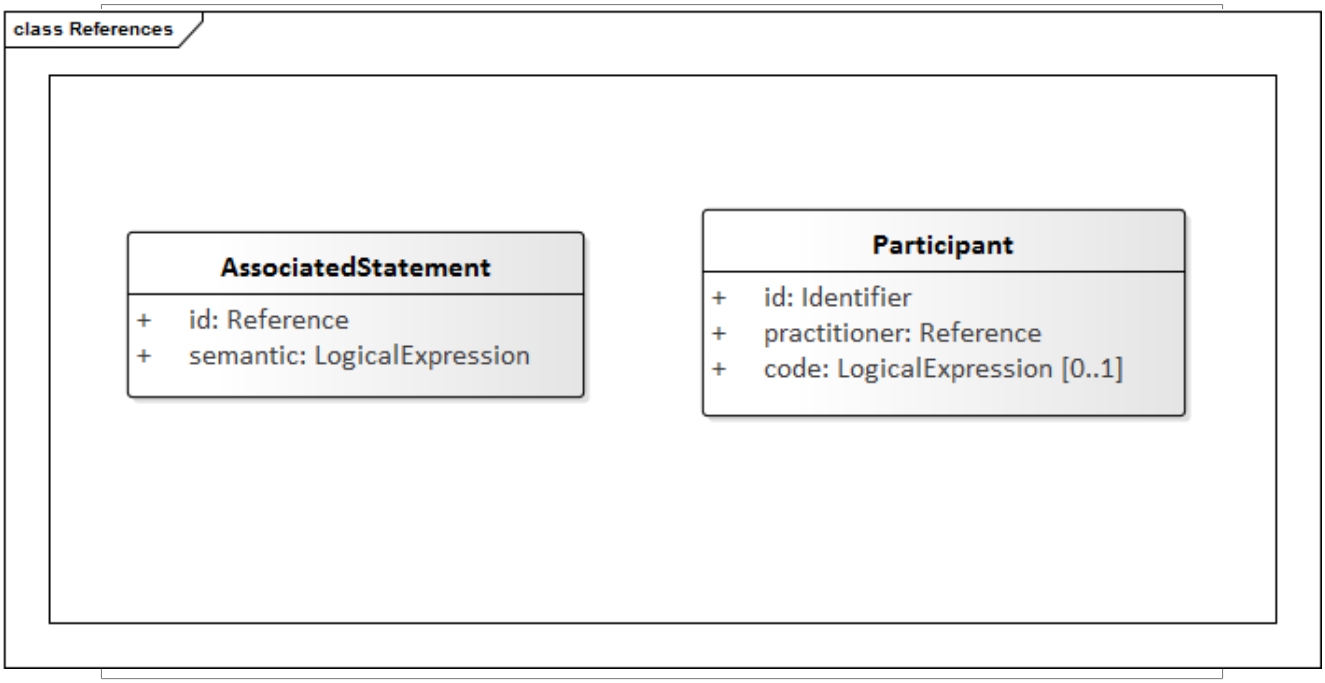


Figure 2.4. References

2.1.4.1. AssociatedStatement

This class specifies how a statement may be associated with another statement.

Attribute	Multiplicity	Notes
id Reference	[1...1]	A reference to the associated statement
semantic LogicalExpression	[1...1]	A logical expression to capture how the target statement is associated(e.g. a precondition, an interpretation, a component).

2.1.4.2. Participant

This class specifies the role/specialties/services that a practitioner may perform relative to the ANFStatement:

- the author
- requested participant
- performance participant

Attribute	Multiplicity	Notes
id Identifier	[1...1]	Unique identifier (e.g. National Provider Identifier).
practitioner Reference	[1...1]	Reference to the participating practitioner.
code LogicalExpression	[0...1]	Role(s) which this practitioner is authorized to perform for the organization.

3. How ANF Works? ANF Clinical Statements

In the context of the ANF Model, a *clinical statement* represents an entry in the patient record that documents, in a structured/computable manner, clinical information related to the patient that is asserted by a particular source, recorded, and potentially verified.

As seen in the *CIMI Clinical Statements* section, clinical information related to the patient can be entered and stored in an EMR in multiple different ways. ANF strives to standardize the structure of clinical statements to eliminate the disparity of clinical information by limiting the design choices a clinical modeler must make. ANF can then act as a consistent transformation target for the multiple differing clinical information representations that currently exist, making this clinical information more easily computable and eliminating the need to create multiple ways to analyze the same data.

3.1. Types of *ANF Statements*

There are two types of ANF Statements:

Performance of Action

A Performance may include the observation of a phenomenon related to patients and their health status or family history, and may also include interventions, such as providing education or administering medications or documenting that a patient is participating in exercise to improve their overall health status.

Request for Action

Requests for clinical testing, active interventions, future goals, or consultation with other providers.

Editorial Rule 4.9

3.1.1. Performance of Action Statements

A Performance of Action statement describes a topic that has previously been performed, and – if applicable - the result that corresponds to the topic. As shown in the examples below, this can range from documenting that a subject of information:

- Was observed to have the presence or absence of a clinical phenomenon
  - Diabetes mellitus is present
  - Diabetes mellitus is not present
  - Dot blot hemorrhage is present

- Underwent a specific test/screening or procedure, and its resultant value, if any
  - Pulse Rate 68 bpm, taken by pulse oximeter
  - Systolic blood pressure 120 mmHg, taken on right brachial artery, using BP cuff adult size, patient in sitting position for at least 5 minutes, urinated not more than 30 minutes prior to measurement
  - Three dot blot hemorrhages
  - Positive screen for fall risk
  - Negative screen for PTSD and depression

- Was administered a medication or other substance

- Patient took one Acetaminophen 500 mg tablet by mouth for pain

- Was provided educational materials
  - Patient was provided with educational materials on diabetes
- Has any other state or specific characteristic that is clinically relevant
  - Family history of breast cancer

3.1.1.1. Presence or Absence of a *Clinical Phenomenon*

Editorial Rule 4.11

Editorial Rule 4.10

Editorial Rule 4.13

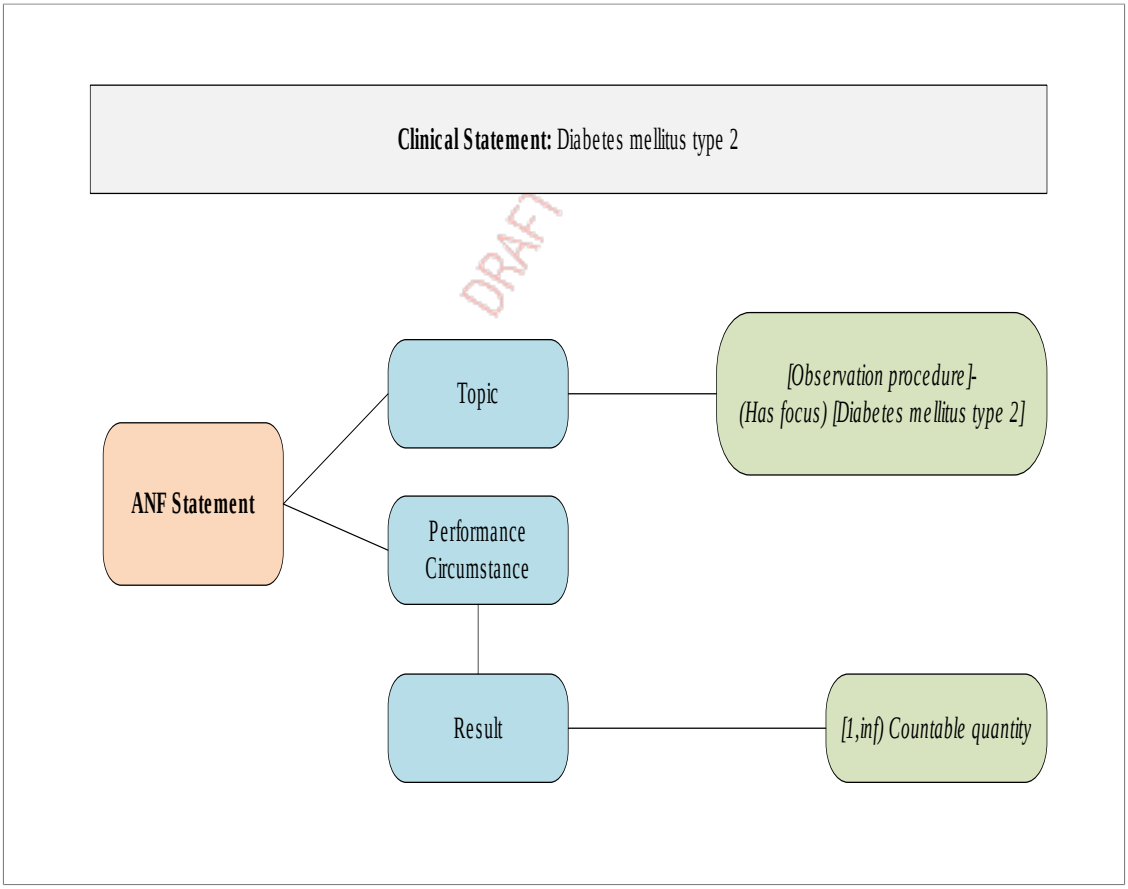


Figure 3.1. Diabetes Mellitus Present Clinical Statement Example

In the Diabetes Mellitus type 2 example above, the Topic is an Observation procedure with a Has focus of Diabetes mellitus type 2. To represent that it is present, the Result is a lowerBound of 1, an upperBound of infinite (inf), and a measureSemantic of "Countable quantity".

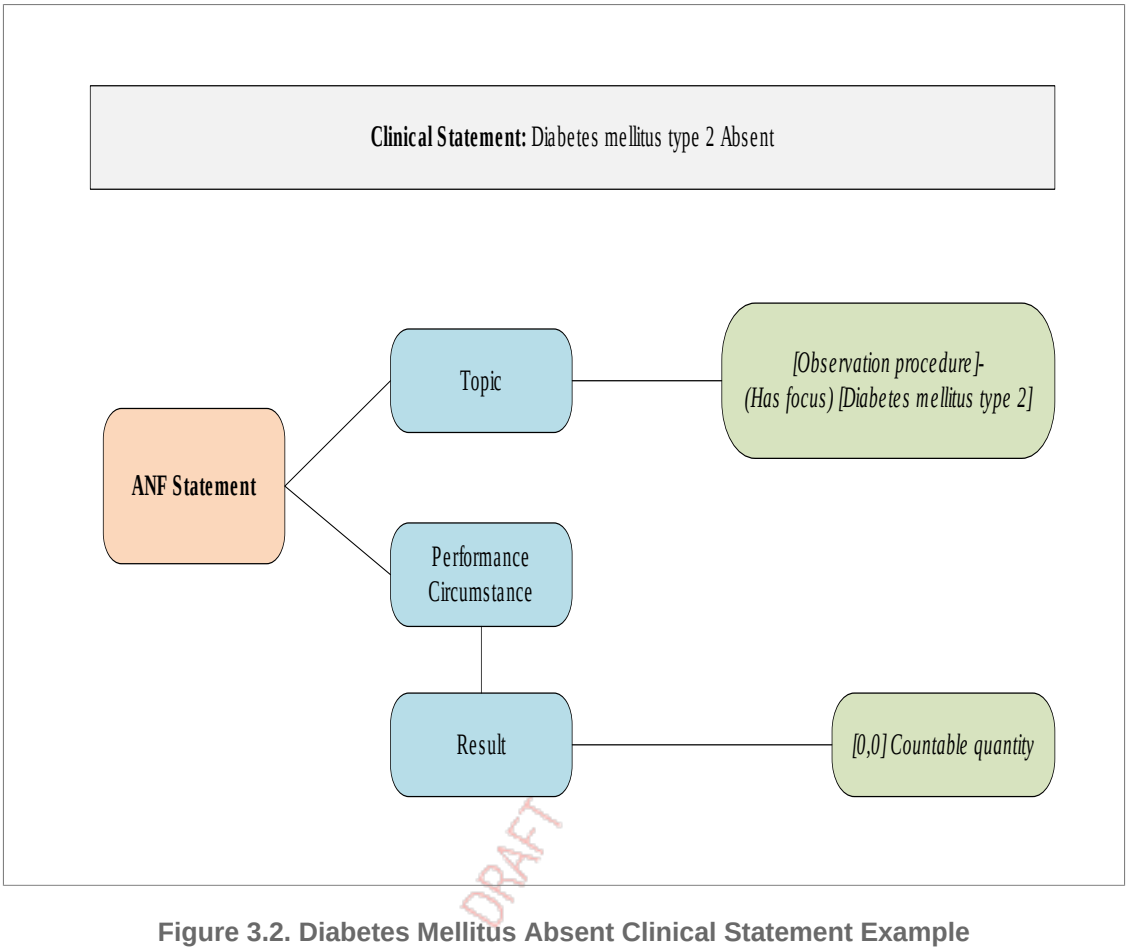


Figure 3.2. Diabetes Mellitus Absent Clinical Statement Example

In the Diabetes Mellitus Type 2 Absent example, the topic is the same as Diabetes Mellitus Type 2 Present example. The difference is in the Result which is represented as an upperBound and lowerBound of zero with the same measureSemantic.

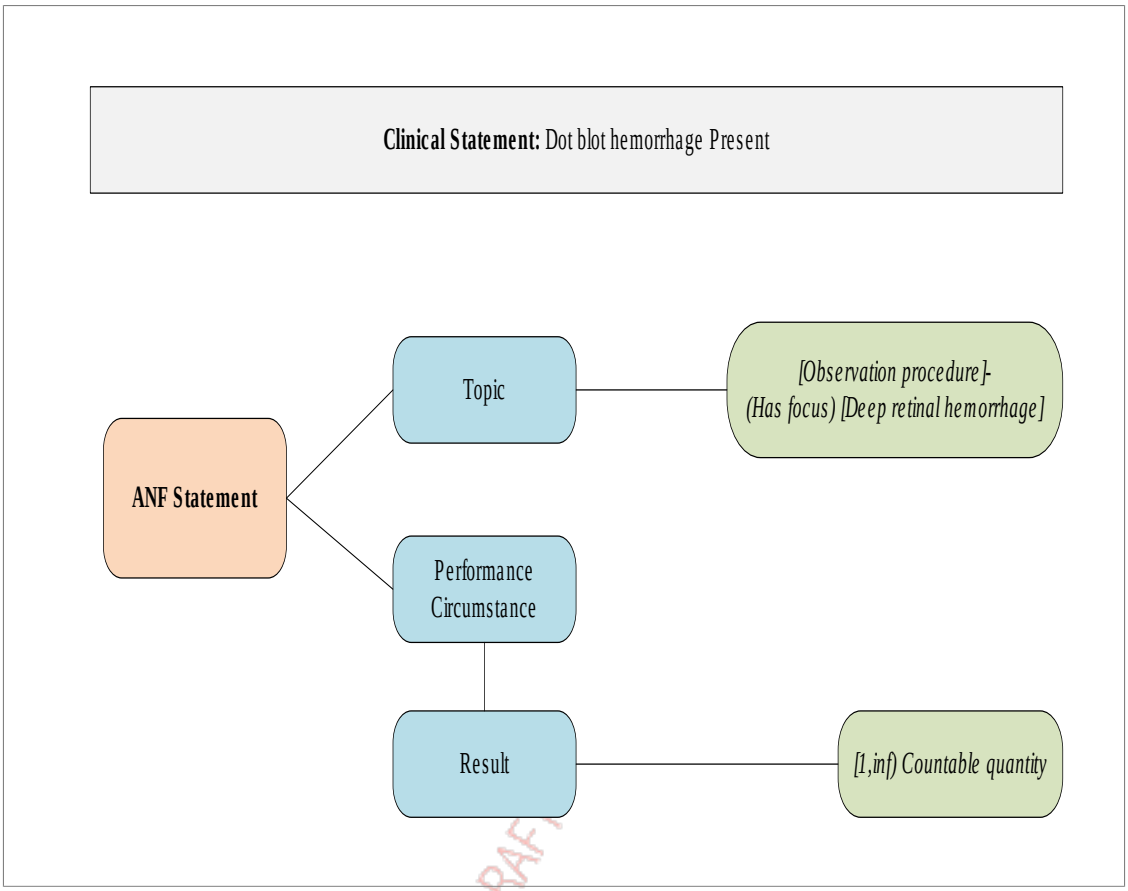


Figure 3.3. Dot Blot Hemorrhage Present Clinical Statement Example

3.1.1.2. Test/Screening or Procedure and Resultant Value

Editorial Rule 3.1. Statement with a Result Value

Any Topic that states a Result that has a value will be specified with the correct upperBound, lowerBound, and measureSemantic. If the Result is a single value, the upperBound and lowerBound will be the same value. If the Result is a range, the upperBound and lowerBound will be specified as such.

Editorial Rule 4.15

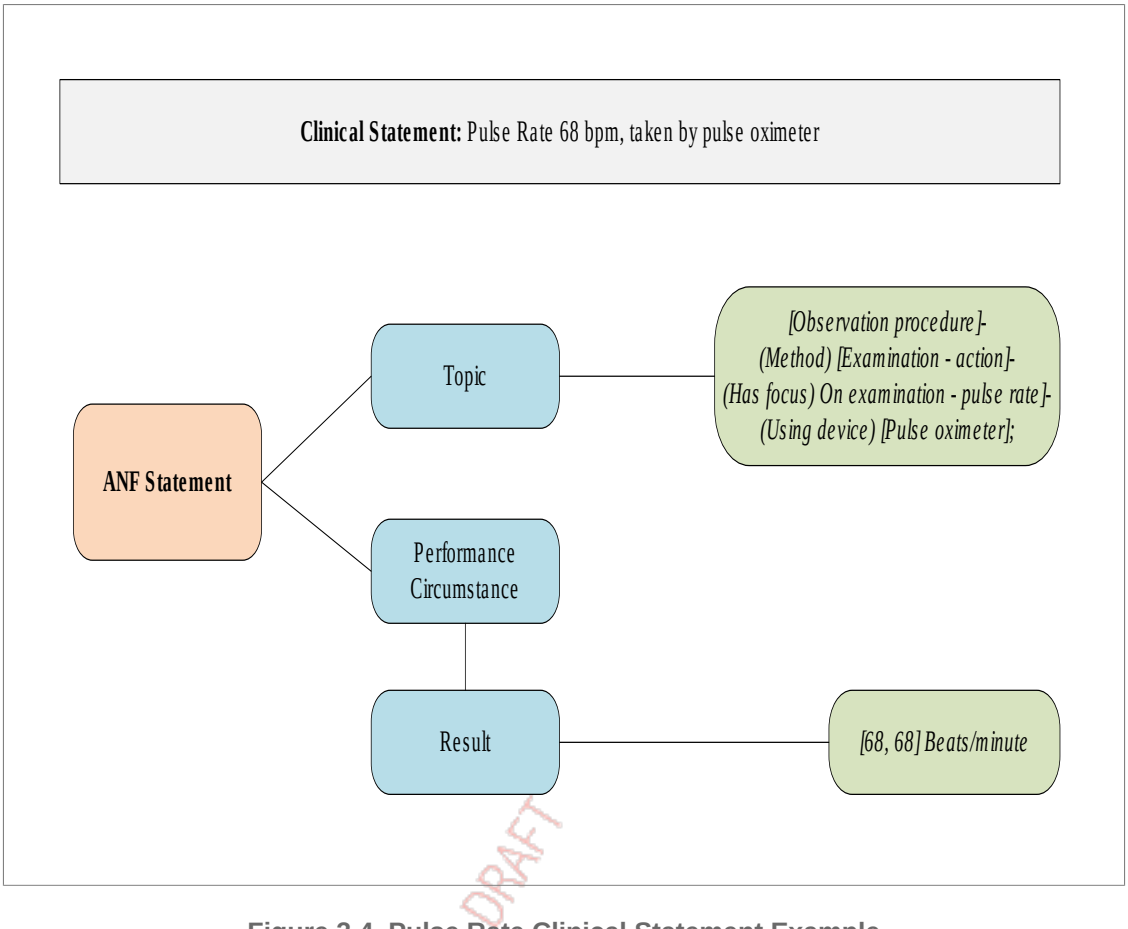


Figure 3.4. Pulse Rate Clinical Statement Example

The Pule Rate example above utilizes a technique, the pulse oximeter device, and contains a resultant value of 68 beats/minute. Since a Result is represented with an upperBound and lowerBound they are both represented as 68 in this case.

Editorial Rule 4.16

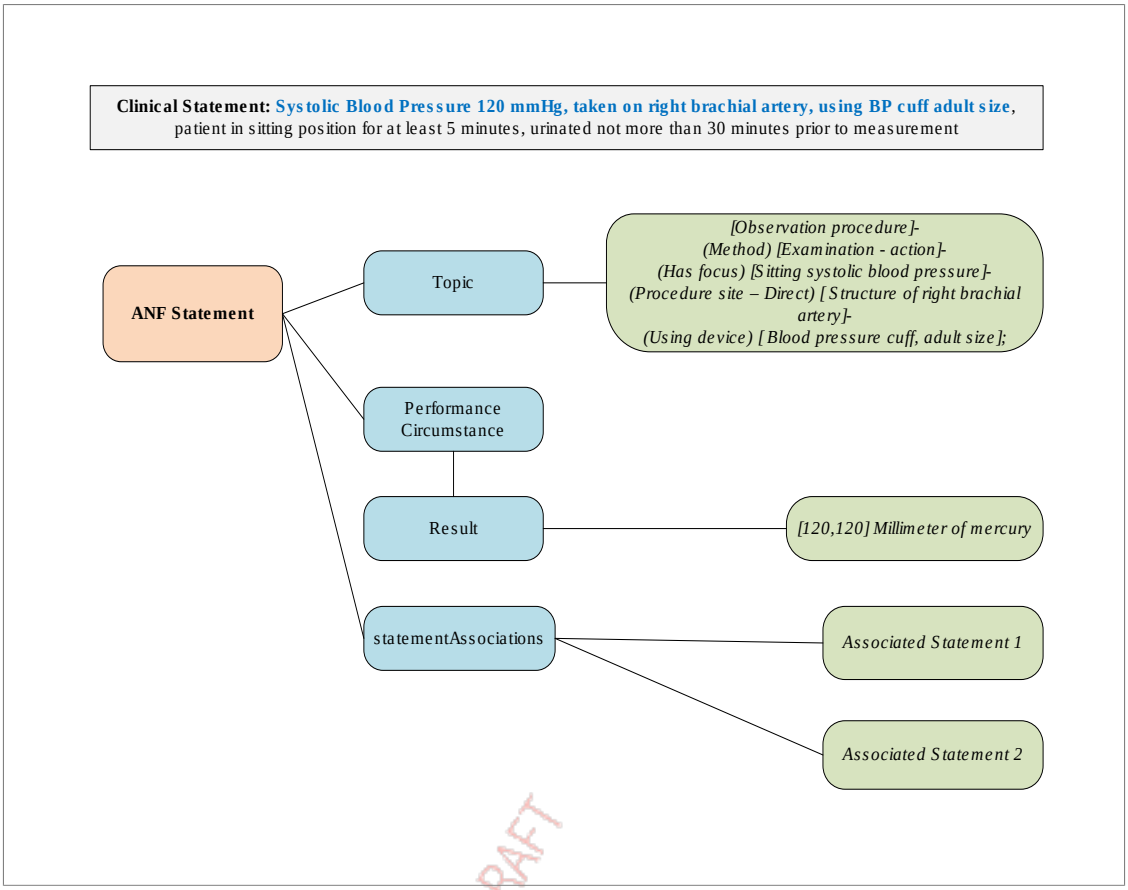


Figure 3.5. Systolic Blood Pressure Clinical Statement Example

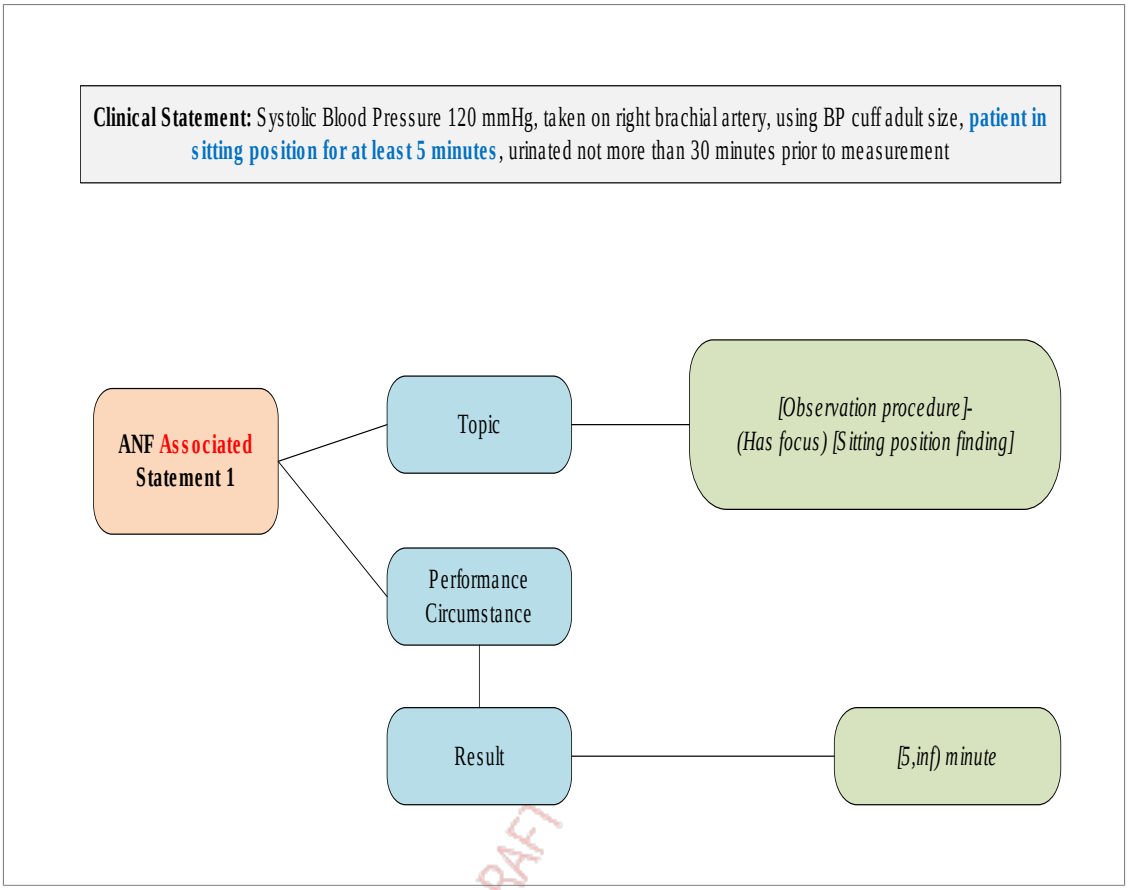


Figure 3.6. Systolic Blood Pressure Associated Statement 1 Example

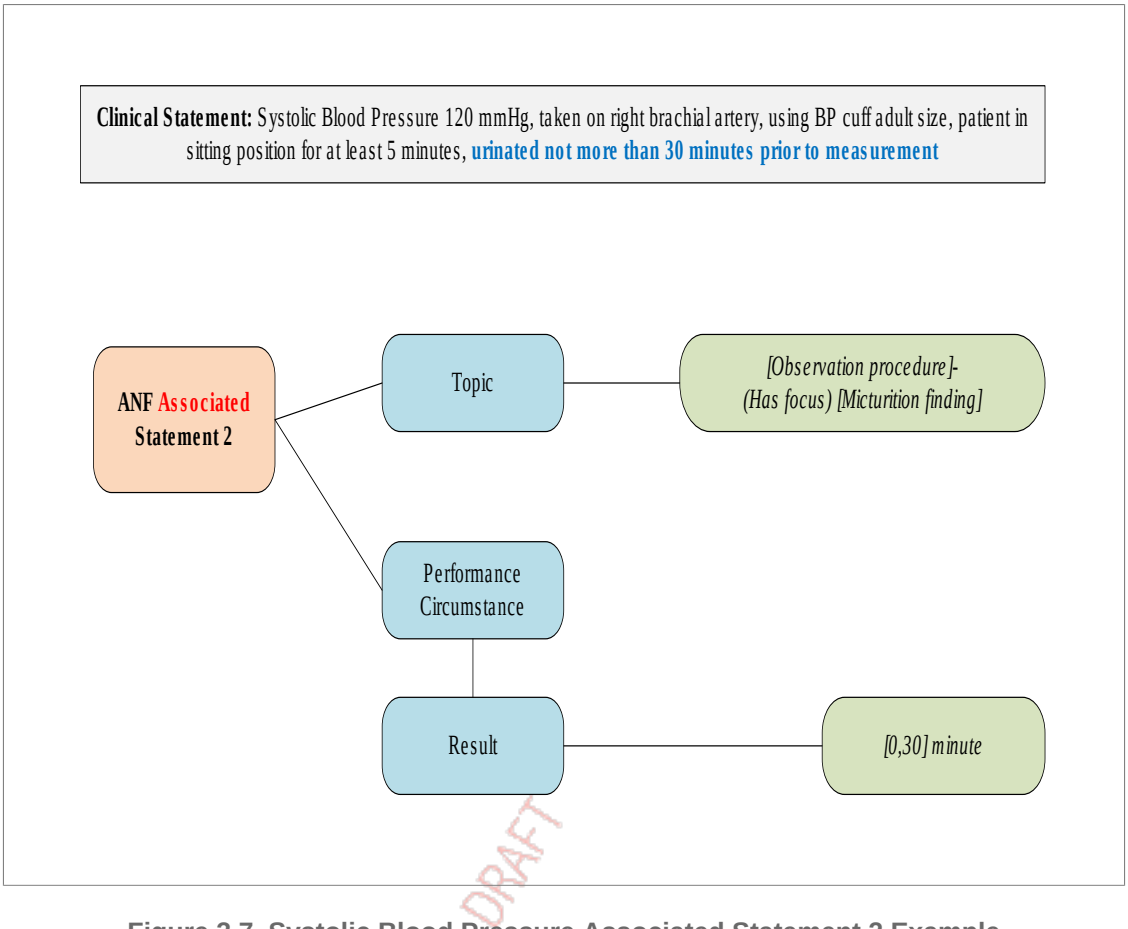


Figure 3.7. Systolic Blood Pressure Associated Statement 2 Example

The systolic blood pressure example above not only includes a technique of using an adult sized cuff, but also includes two prerequisites that are represented as separate associated ANF Statements. In the Associated Statements we see examples of Results having a range of values using the upperBound and lowerBound.

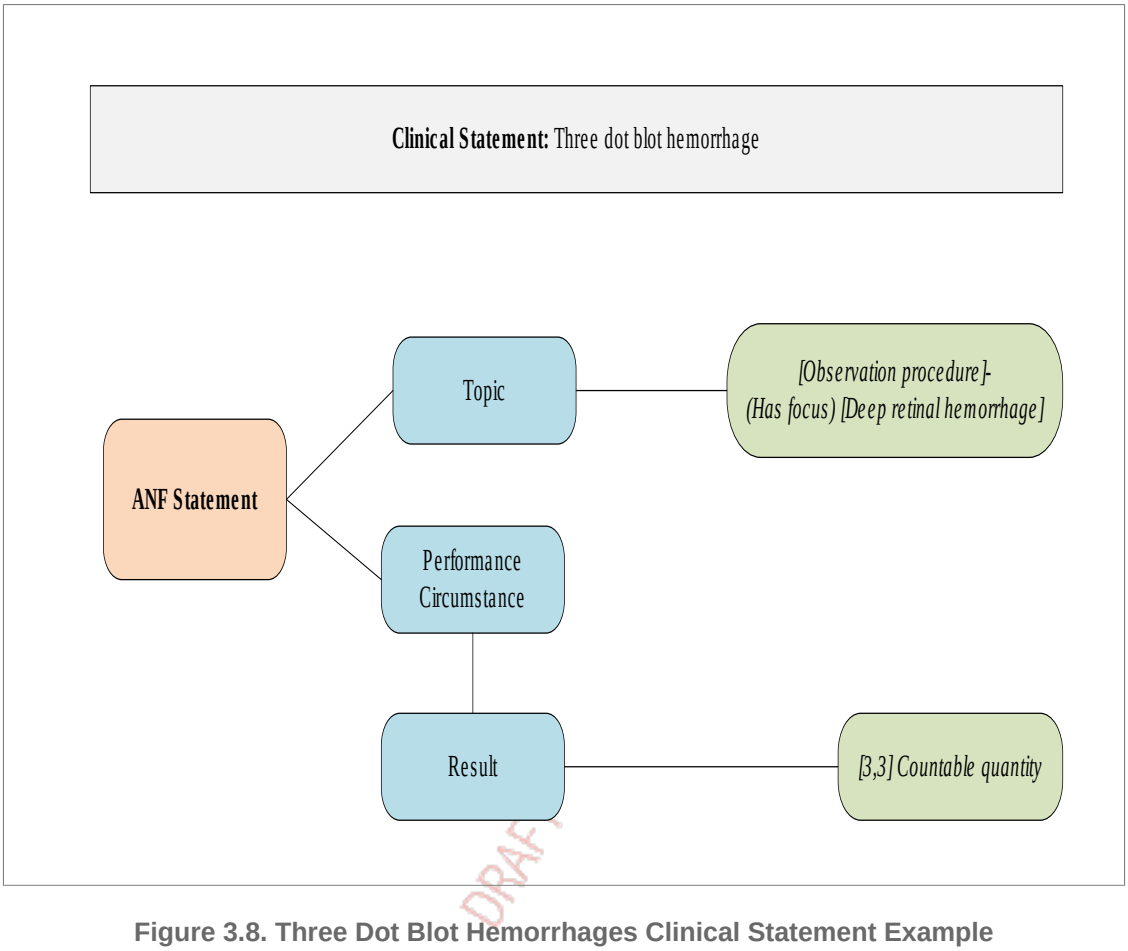


Figure 3.8. Three Dot Blot Hemorrhages Clinical Statement Example

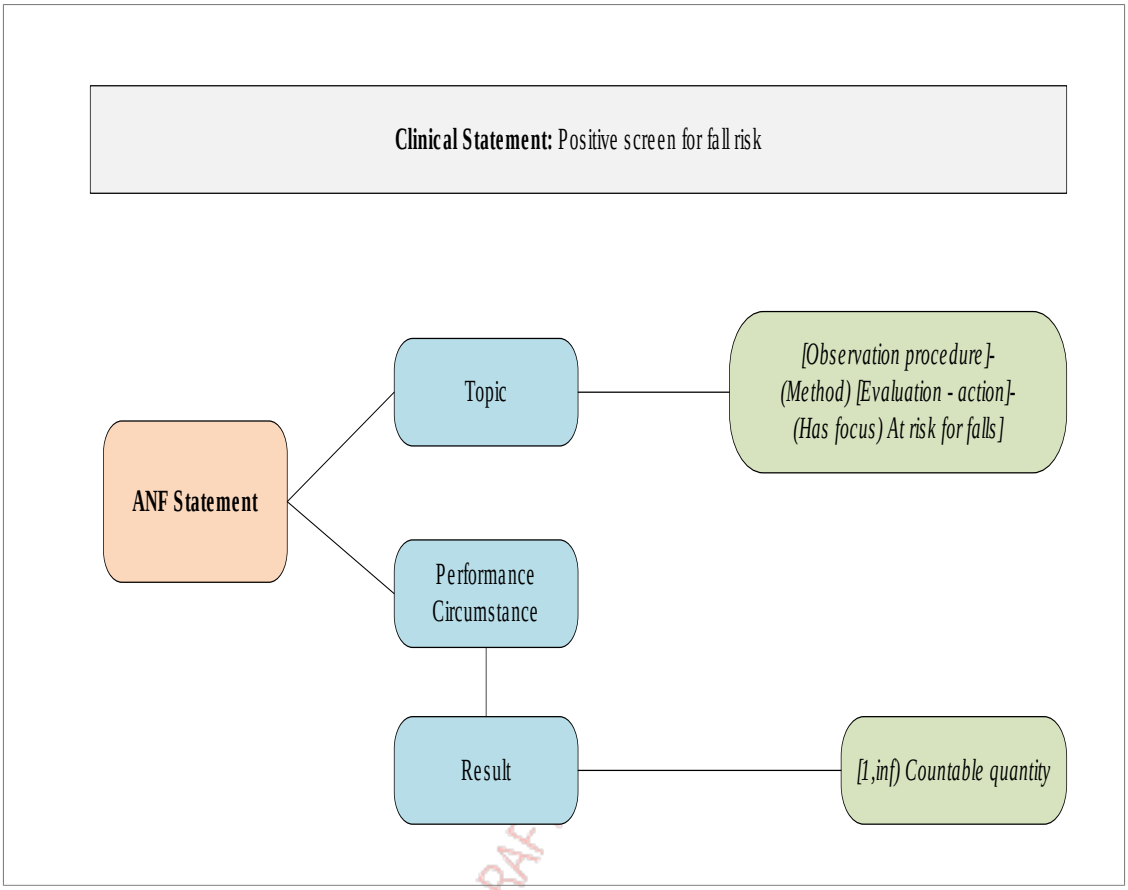


Figure 3.9. Positive Screen for Fall Risk Clinical Statement Example

Editorial Rule 3.2. Multiple Topics

For the purposes of ANF, a statement is a request or performance of an action that has to be able to exist on its own. Therefore a narrative would be separated into multiple clinical statements if it contains multiple requests or performance of actions that could exist independently of each other. For the narrative "Negative screen for PTSD and depression", two separate ANF Statements would need to be created and associated to each other. However, if the narrative represents two or more actions that are performed as a single activity at the same time without the need for stopping the action then a single topic would be used. For example, "Lumbar/Thoracic Spine CT" would be represented with a single topic as it represents a single activity that is performed at the same time even though a Lumbar CT and a Thoracic CT could be done separately.

Editorial Rule 3.3. Associated Statements

Use an associated statement when it is important for the interpretation of one statement that the others were observed, performed, or requested. Also, if there is some implicitness that the two statements are related (pleural empyema with fistula) or that they are unrelated (Akinetic seizure without atonia) then the two statements should be associated.

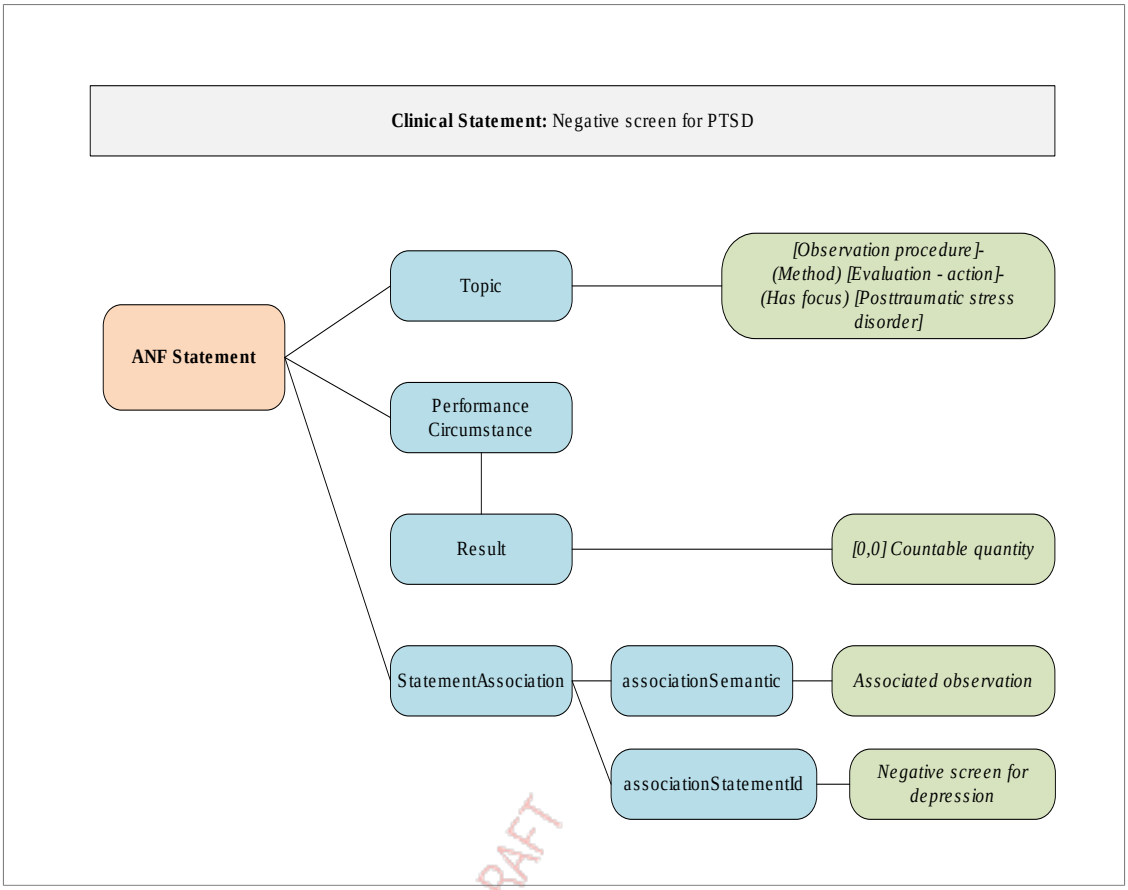


Figure 3.10. Negative Screen for PTSD Clinical Statement Example

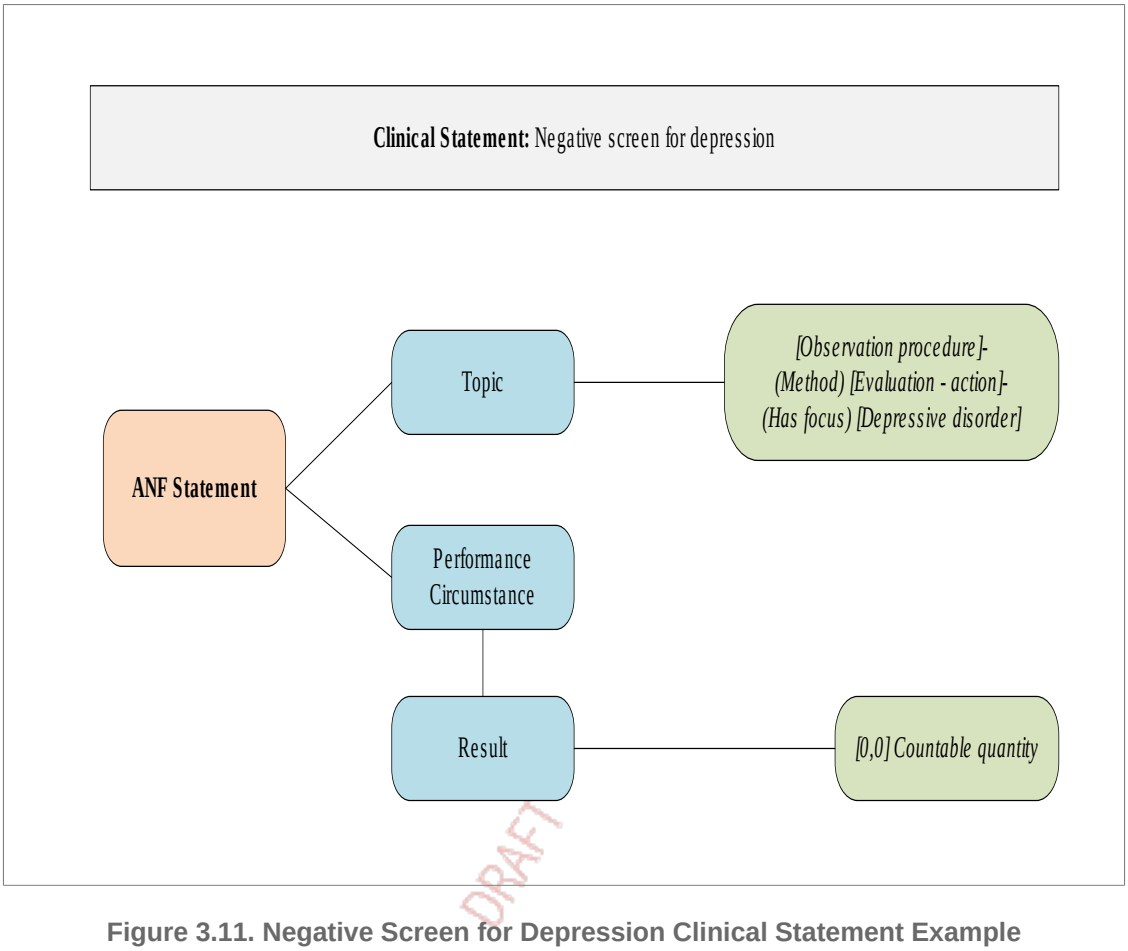


Figure 3.11. Negative Screen for Depression Clinical Statement Example

3.1.1.3. Administering a Medication or Other Substance

Editorial Rule 4.23

Editorial Rule 3.4. Administration of Medication Topic - Performance of Action

To represent the performance of an administration of medication, the Topic will be built using the Administration of substance concept. All Administration of substance concepts will be refined with the substance and dose form and strength being requested. If Route of administration exists, then it will also be added.

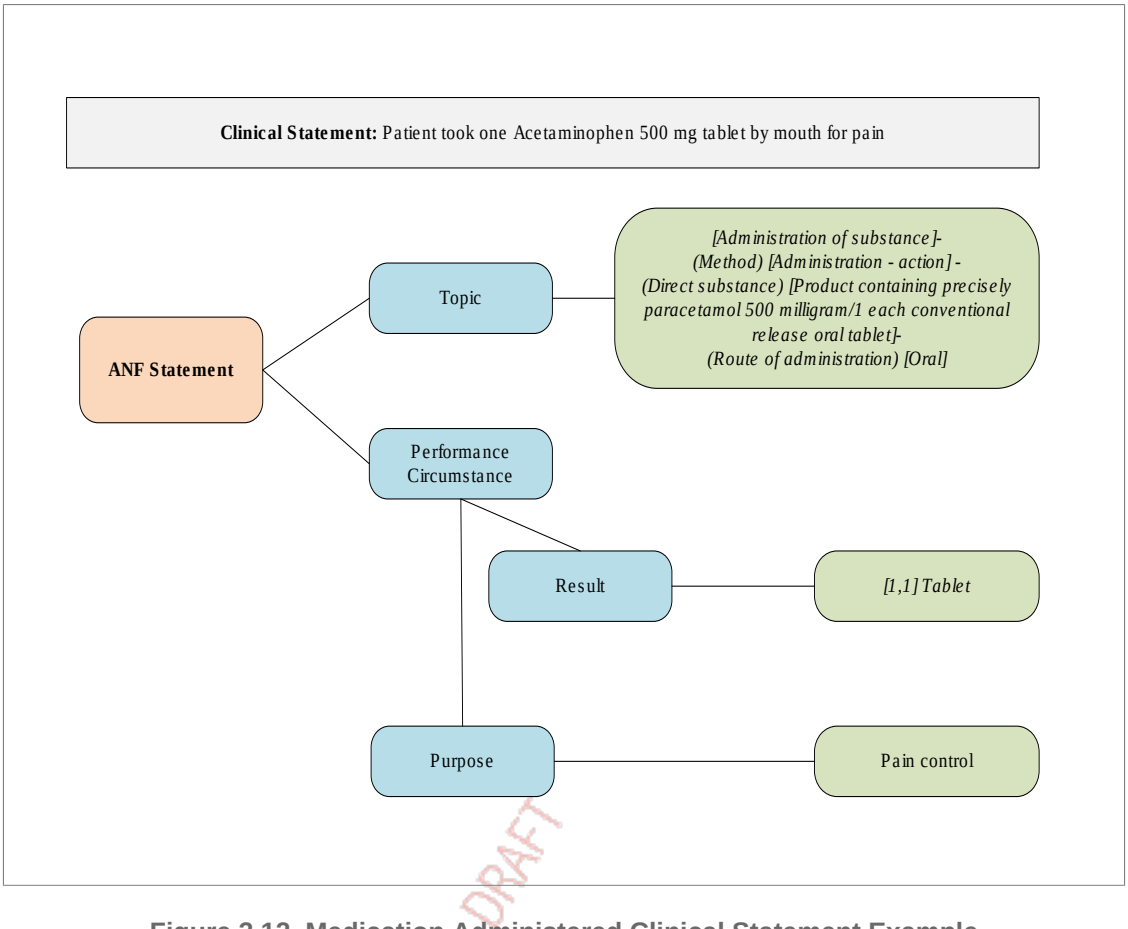


Figure 3.12. Medication Administered Clinical Statement Example

In the medication example above a purpose is specified using Pain control which has a focus of pain. The Topic is built using Administration of substance with a Direct substance specifying the pharmaceutical product and a Route of Administration specifying Oral.

3.1.1.4. Provision of Educational Materials

Editorial Rule 3.5. Topic for All Other Procedures

Any other action that was performed would be represented by a Procedure concept with any of the approved terminology procedure attributes applied.

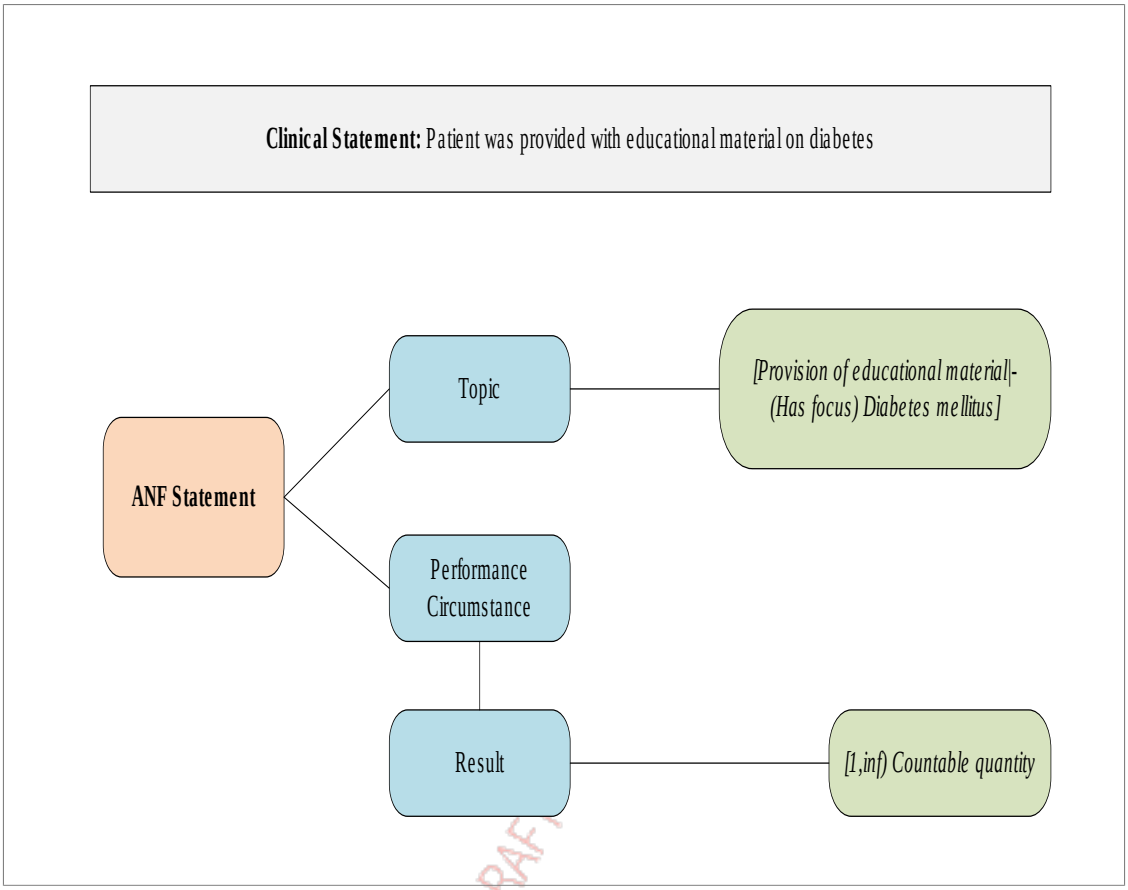


Figure 3.13. Education Provided Clinical Statement Example

In this example, the concept Provision of educational material is used with a Has focus of Diabetes mellitus.

3.1.1.5. Other States or Specific Characteristics That Are Clinically Relevant

Editorial Rule 3.6. subjectOfInformation

The subjectOfInformation is used to represent who the statement is about. This is normally the patient (Subject of record) unless explicitly stated otherwise, for example Mother, Sibling, Donor, etc.

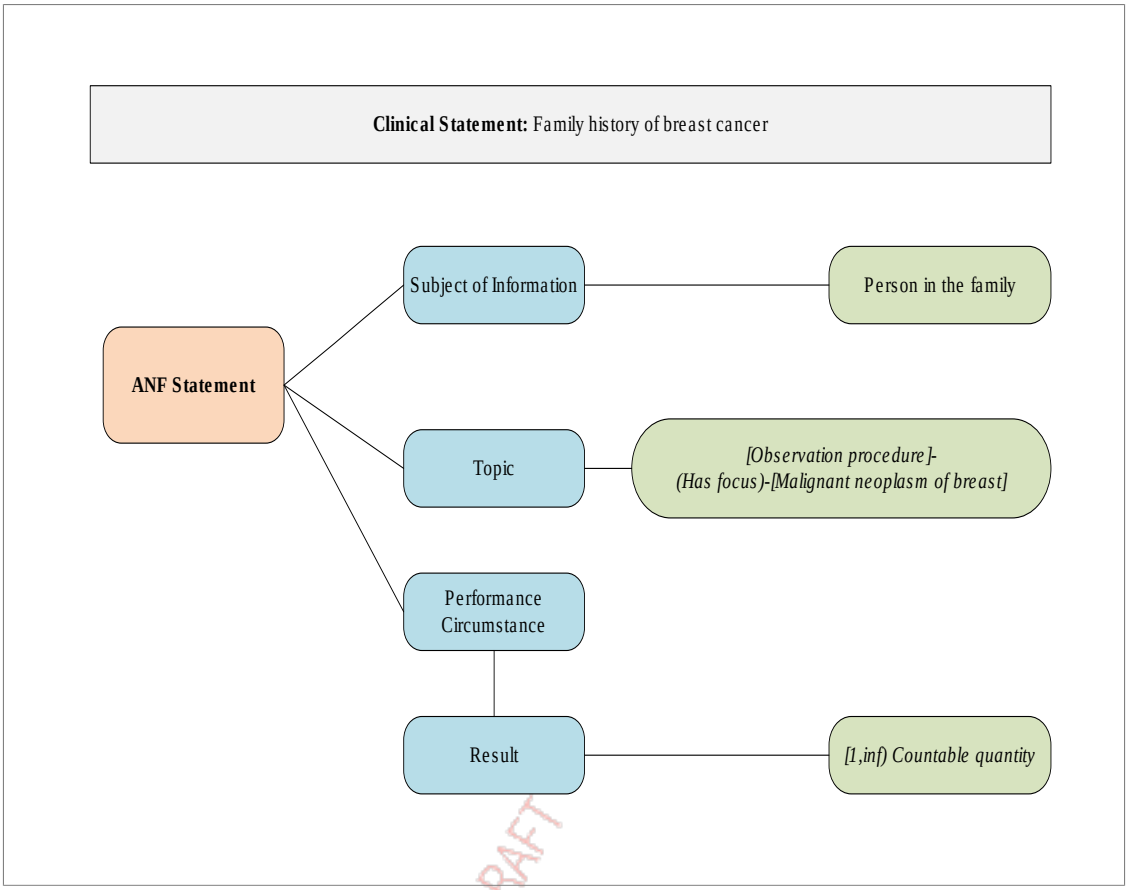


Figure 3.14. Family History Clinical Statement Example

In the Family history of breast cancer example we see that the Family history is represented by the Subject of information with a value of Person in the family.

3.1.1.6. Normal Range Information or Health Risk Specified

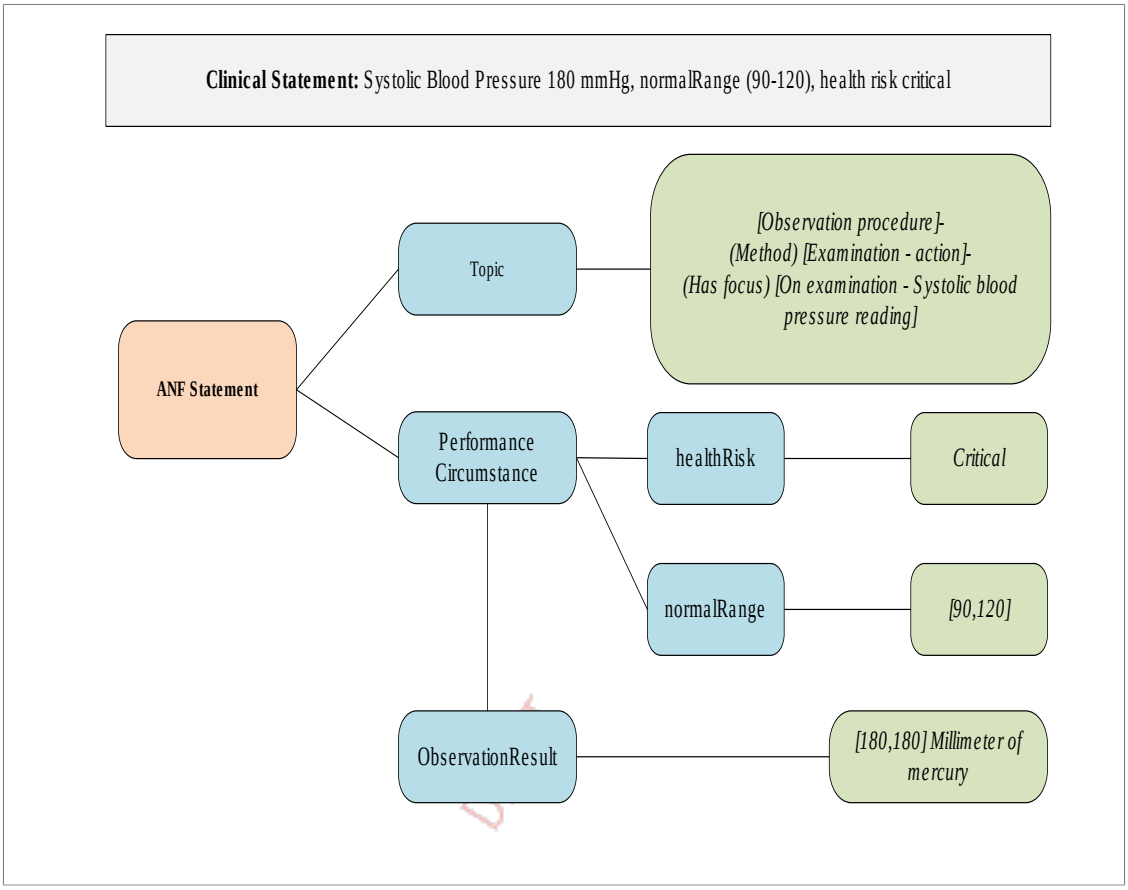


Figure 3.15. Systolic Blood Pressure Observation Result Clinical Statement Example

Systolic Blood Pressure for adults has a normal range of 90-120 and is represented in the normal-Range. Systolic Blood pressure above 180 would represent a critical health risk and is represented in the healthRisk.

3.1.2. Request Clinical Statements

A Request for Action clinical statement describes a request made by a clinician. Most of the times, but not always, the object of the request (e.g., lab test, medication order) will be fulfilled by someone other than the clinician (e.g., lab technician, pharmacist) making the request. All information about the request will be documented in this clinical statement, including information about details relating to the request, such as patient must fast for 12 hours before having a lipids blood test.

Examples of Request clinical statements:

- Request for Rheumatoid factor 1 time routine
- Request for X-ray chest to evaluate for heart failure
- Cardiology referral
- Ribavirin 200 mg capsule oral, take 2 capsules every morning
- Advised to participate in tobacco cessation counseling once a week.

3.1.2.1. Request Examples

Editorial Rule 3.7. Timing - Request for Action

The Timing will always represent a future time in a Request for Action ANF Statement. Therefore, the Measure used in the Timing will be for a future time.

Editorial Rule 3.8. Laboratory Procedure Topic

For Laboratory procedures, the Topic will be built using a Laboratory Procedure concept. These concepts can be further refined.

Editorial Rule 3.9. Priority

Priority is used to represent the priority for which the request is to be carried out. By default a Request will be considered "routine" unless otherwise specified.

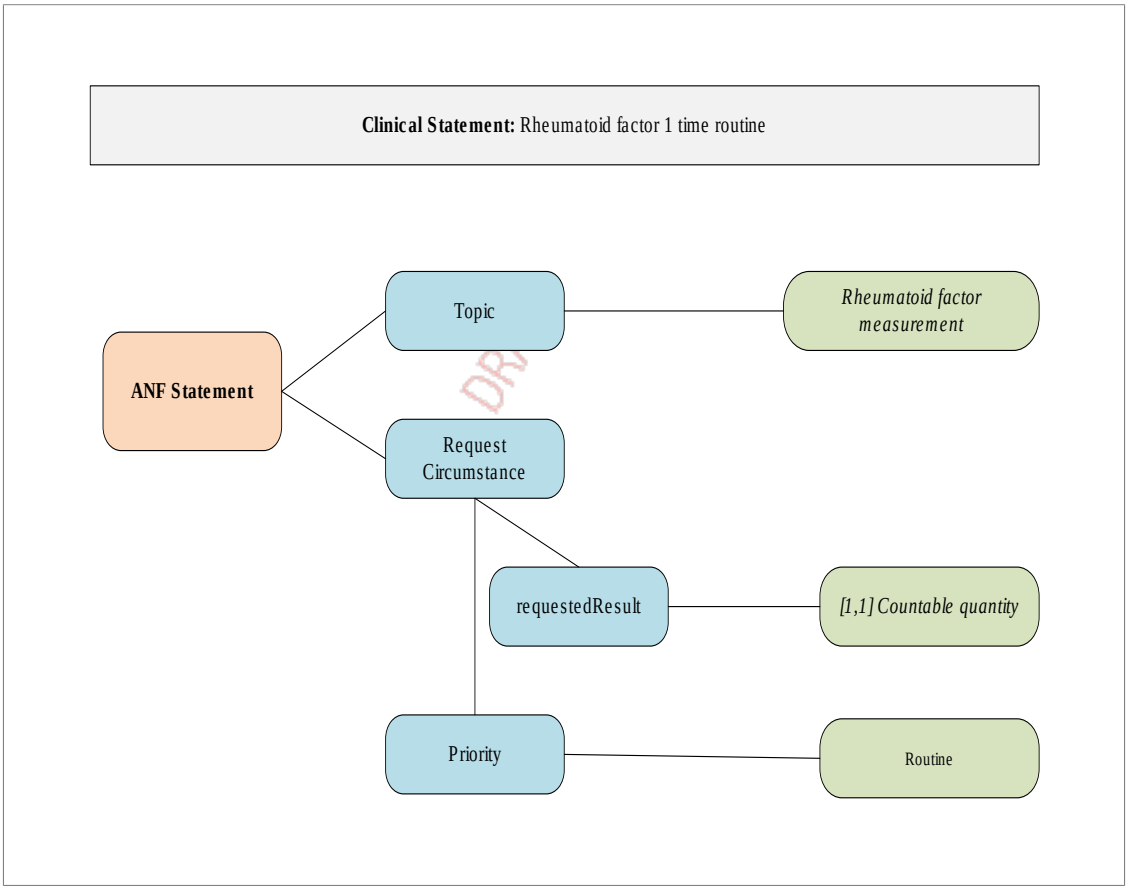


Figure 3.16. Lab Request Clinical Statement Example

The Laboratory Request example above shows how the topic is built using a laboratory procedure concept, with no refinements in this case. It also has a Priority of Routine as stated in the narrative description.

Editorial Rule 3.10. Imaging Procedure Topic

For Imaging procedures, the Topic will be built using an Imaging Procedure concept. These concepts will be further refined with a Method, Procedure site - Direct and (if appropriate) a laterality for those sites that are lateralizable.

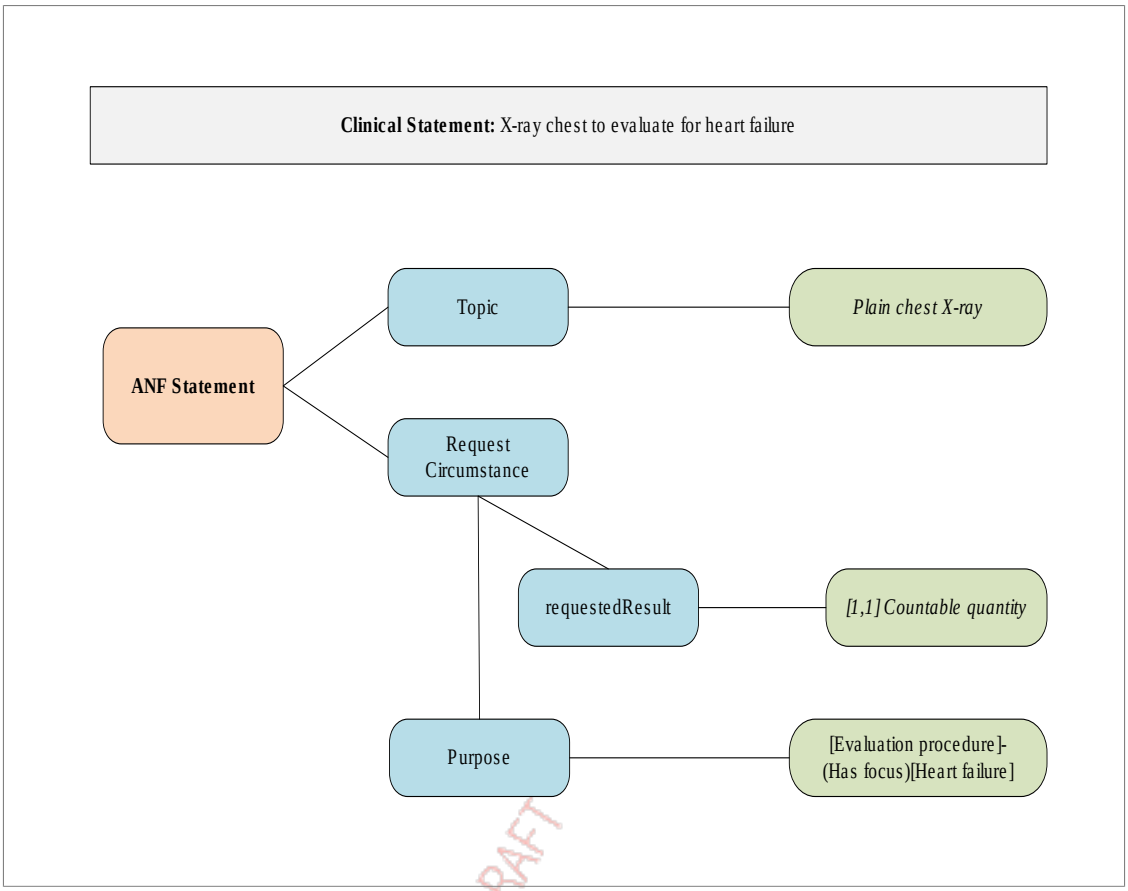


Figure 3.17. X-Ray Request Clinical Statement Example

The Imaging Request example above is built using a subtype of image procedure concept and includes a Purpose to record why the procedure is being done.

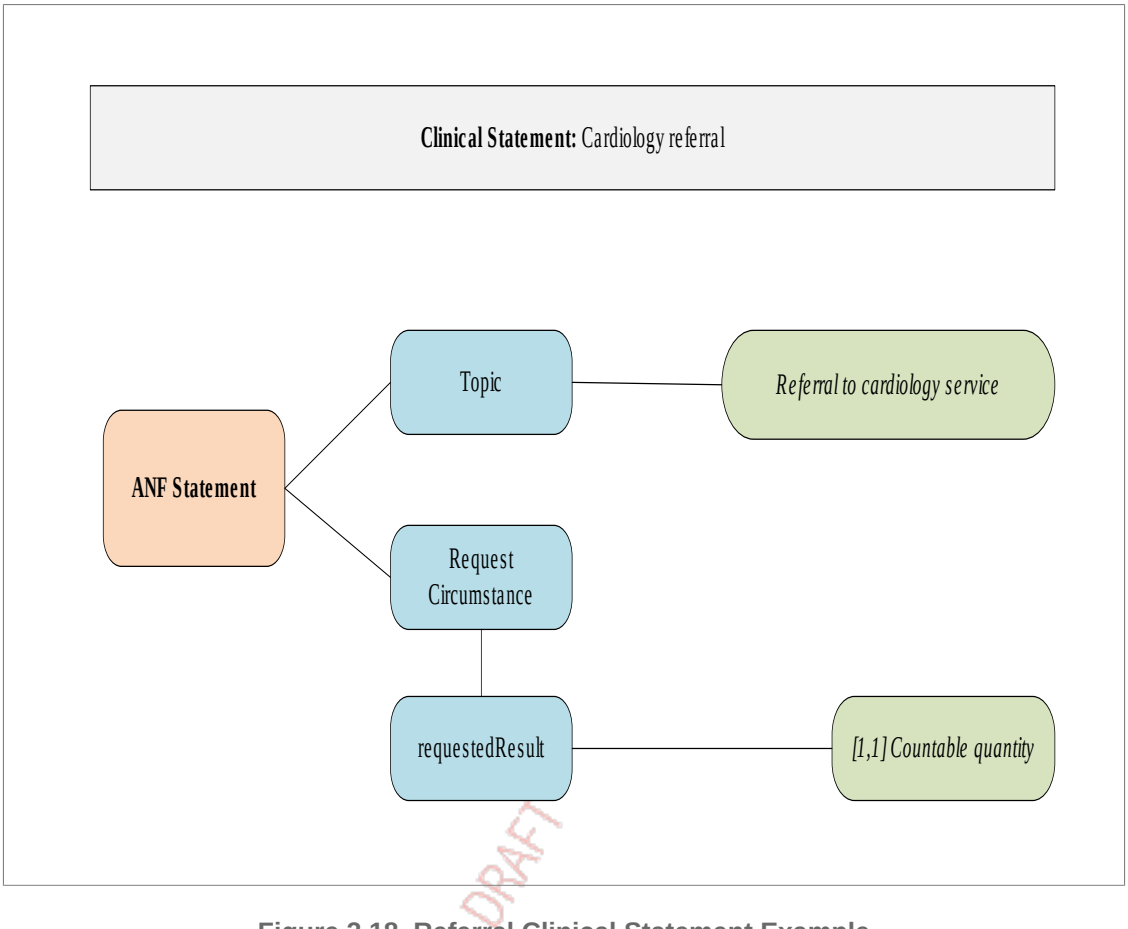


Figure 3.18. Referral Clinical Statement Example

Editorial Rule 3.11. Administration of Medication Topic - Request for Action

For requesting the administration of medication, the Topic will be built using the Administration of substance concept. If the narrative includes information about a refill, that information is currently represented as an Narrative Circumstance. All Administration of substance concepts will be refined with the substance and dose form and strength being requested. If Route of administration exists, then it will also be added.

Editorial Rule 3.12. Repetition

Repetition is used to represent when an action is requested for more than a single occurrence. Repetition is an optional component for a RequestCircumstance. A Request Component contains five Measures that are used to further define the parameters of the Repetition:

- *periodDuration:*This required field is used to represent how long a repetition should persist. If it is not specified, a default value of [0,inf) will be used. An example of periodDuration would be "Take for 3 weeks".
- *periodStart:* This required field is used to represent when a repeated action should begin. If it is not specified, a default value of [0,inf) will be used. An example of periodStart would be "NOW".
- *eventSeparation:*This required field is used to represent how long between actions. If it is not specified, a default value of [0,inf) will be used. An example of eventSeparation would be "Every 2 weeks".
- *eventFrequency:*This required field is used to represent how often the action should occur. If it is not specified, a default value of [0,inf) will be used. An example of eventFrequency would be "Use 3 times per week".
- *eventDuration:*This is an optional field that is used to represent how long every action should last "Use for 2 weeks".

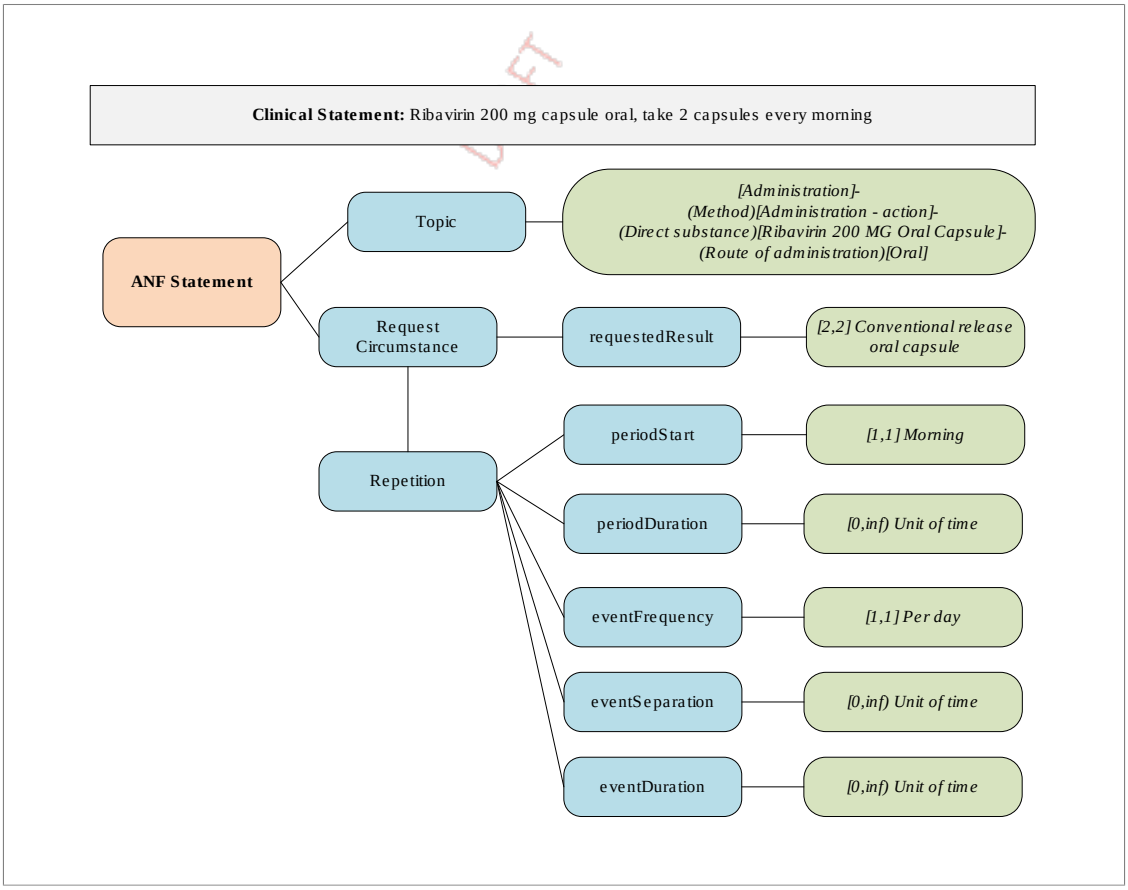


Figure 3.19. Medication Request Clinical Statement Example

The Medication request example represents one of the more complicated ANF Statements that includes not only the Topic, but also the Repetition information for completing the request.

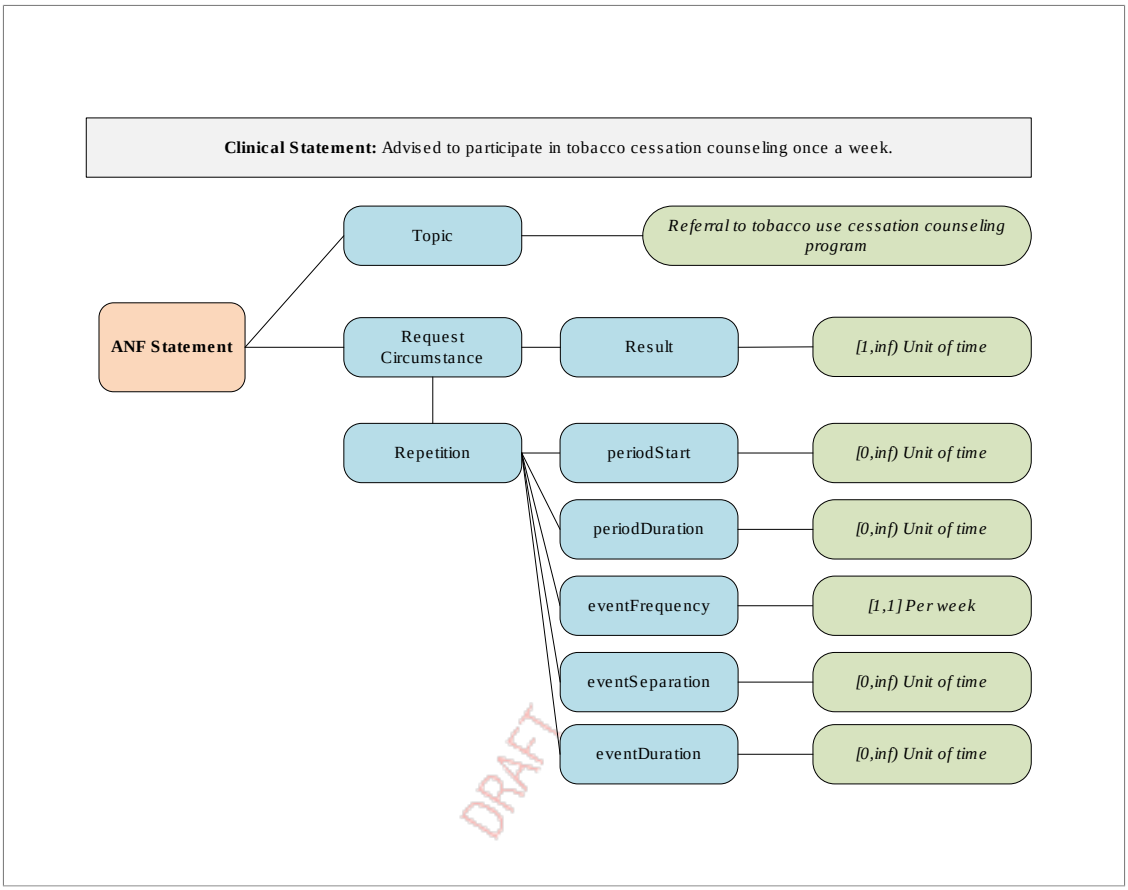


Figure 3.20. Counseling Request Clinical Statement Example

In this example we see Repetition used only to define the eventFrequency while the other Repetition information is defaulted to [0,inf) Unit of time.

4. Methodology - ANF Modeling Principles and Rules

4.1. ANF Modeling Principles

A. As an overarching principle we favor the simpler, consistent model over more complex models that allow for multiple inconsistent representations. As such, the following principles have been used when designing the ANF model:

- **Overall Model Simplicity:** In cases where different principles collide, we shall favor the enhancement of simplicity of the entire system over simplicity in one area of the system.
- **Convention Over Configuration:** Convention over configuration (also known as coding by convention) is a software design paradigm used by software frameworks that attempts to decrease the number of decisions that a developer using the framework is required to make without necessarily losing flexibility.
- **Model Consistency:** Patterns should allow the consistent representation of information that is commonly shared across models. For instance, attribution and participation information should be captured consistently. Failure to do so forces implementers to develop heuristics to capture and normalize attribution information that is represented or extended differently in different classes (e.g., FHIR).
- **Model Should Avoid Semantic Overloading (semantic precision):** Semantic overloading occurs when a model attribute's meaning changes entirely, depending on context. While the refinement of the semantics of an attribute in a subclass is acceptable, a change of meaning is problematic. For instance, in FHIR, the Composition class defines an attribute called Subject. In some subclasses, the attribute may be the entity that this composition refers to (e.g., the patient in a medical record). In other cases, it is the topic being discussed by the composition (e.g., a medication orderable catalog).
- **Assumption-free:** Implied semantics must be surfaced explicitly in the model.
  - **Example:**Some things implicit in the statement, "I ordered a book from Amazon" are: paying for the book, delivery of the book to some location, and the transfer of ownership of the book from the vendor to the client.

B. **Composition Over Inheritance:** Composition over inheritance (or composite reuse principle) in object-oriented programming is the principle that classes should achieve polymorphic behavior and code reuse by their composition (by containing those instances of other classes that implement the desired functionality) rather than inheritance from a base or parent class.

   To favor composition over inheritance is a design principle that gives the design higher flexibility. It is more natural to build business-domain classes out of various components than trying to find commonality between them and creating a family tree.

   Initial design is simplified by identifying system object behaviors in separate interfaces instead of creating a hierarchical relationship to distribute behaviors among business-domain classes via inheritance. This approach more easily accommodates future requirements changes that would otherwise require a complete restructuring of business-domain classes in the inheritance model.

C. **ANF Clinical Statements Represent the Minimum Disjoint Set:** Analysis Normal Form (ANF) clinical statements represent the minimum disjoint set of statement topic, result, and circumstance and may not be further specified.

D. **Clinical Statement Model Stability:** Stable means that the model can still meet unanticipated requirements without having to change. It is not acceptable to change the model every time a new way to administer a drug or to treat a condition is identified. By representing these types of potentially dynamic concerns in the terminology expressions, as opposed to static fields in a class structure, we do not have to change the model every time something new is discovered. As Terry Winograd said, anticipating breakdowns, and providing a space for action when they occur, is a design imperative.

   In some regards, in this context “stable” means “not brittle.” A model easily broken by changes that someone could anticipate is one possible definition of brittle. A stable model is critical in the phase of a known changing landscape. We do that by isolating areas of anticipated change into a dynamic data structure. That dynamic data structure may also be immutable in an object that represents a clinical statement.

E. **Reusability:**Architectural patterns should encourage class reusability where possible. Reusability may further refine encapsulation when composition is considered.

F. **Design by Composition and/or Class Specialization:** The capture of additional model expressivity must be captured by composition and/or by class specialization. The modeling approach should avoid the use of design by constraint (except for terminology binding and attribute type constraints) as it violates proper decoupling and encapsulation. An example of design by constraint is to create a single procedure class containing all attributes for all known procedures and constraining out irrelevant attributes in a more specialized model. This approach is very difficult to implement and violates numerous object-oriented best practices.

G. **No False Dichotomies:** Dichotomies that are not completely disjoint (mutually exclusive) lead to arbitrary classification rules and result in ambiguity based on different assumptions about the domain. These must be avoided.

H. **Model Symmetry:** There should be symmetry in the models wherever we can have it.

I. **Iterative development and validation of model using use cases:** ANF has been developed using an iterative approach evaluating the model with narrative use cases. Examples of narratives used to evaluate the model can be found in the Appendix.

4.2. Shared Modeling Guidelines

All ANF statements share some common model components. The following modeling guidelines can be used to properly model a narrative into the appropriate components of a single statement or a statement that has multiple associated statements. For the purposes of ANF, a statement is a request or performance of an action that has to be able to exist on its own. Therefore a narrative would be separated into multiple clinical statements if it contains multiple requests or performance of actions that could exist on their own.

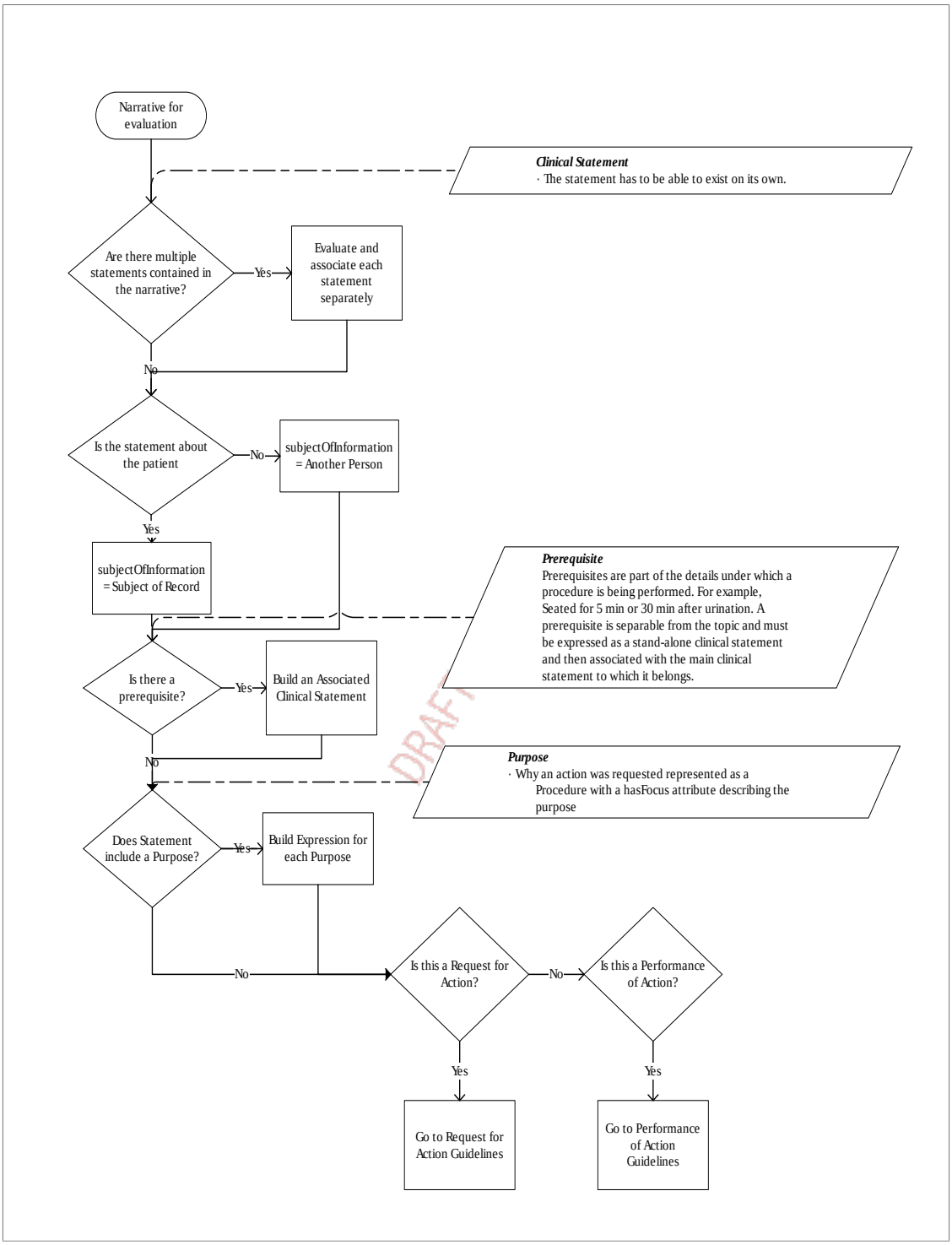


Figure 4.1. Shared Modeling Guideline Decision Tree

Technique: : A device used, a method applied, or a temporary state in which the patient was **actively** placed **during** performance of the action.

- Actions can be performed by various techniques. As opposed to the action itself, which is *what* is carried out, the technique defines *how* the action is done in general or in a particular instance.

- The use of the device or the method that is applied must start during the performance of the action.
- A technique is inseparable from the topic and cannot be expressed as a stand-alone clinical statement.
  - Example: Systolic blood pressure 120 mmHg, taken on right brachial artery. *"Taken on right brachial artery"* is inseparable from the topic and cannot be expressed as a stand-alone clinical statement. It therefore constitutes a technique and will be modeled as part of the topic.
  - Example: Seated systolic blood pressure 120 mmHg. Seated relates to how the action was done and is an inseparable part of the topic. For the narrative "Systolic Blood Pressure 120 mmHg, taken on right brachial artery, using BP cuff adult size, patient in sitting position for at least 5 minutes, urinated not more than 30 minutes prior to measurement" while seated is not explicitly stated as the technique it is implied that the blood pressure was taken in the seated position and therefore would be represented in the topic in addition to a separate statement representing that the patient was in the seated position for at least 5 minutes.

Prerequisite: A prerequisite is a **state** that **must** exist before something else can happen or be done. Prerequisites are part of the details under which a procedure is being performed. The state must exist prior to the performance of the action.

- The state that must exist pertains to
  - the subject of record (e.g. patient)
  - the environment (e.g. necessary room temperature, required time of day)
- A prerequisite is separable from the topic and can be expressed as a stand-alone clinical statement
  - Example: Systolic blood pressure 120 mmHg, taken with patient in sitting position for 5 minutes. *"Patient in sitting position for 5 minutes"* is separable from the topic and exists prior to the performance of the action and therefore constitutes a prerequisite. The "sitting position" portion of the prerequisite also specifies a technique for performing the blood pressure measurement and therefore would be included in the topic.

subjectOfInformation: The subjectOfInformation is used to represent who the statement is about. This is normally the patient unless explicitly stated otherwise.

Purpose: The purpose is why an action was requested. The purpose of the topic is represented with either an Evaluation procedure or Therapeutic procedure with a hasFocus attribute describing the purpose.

4.3. Request for Action Guidelines

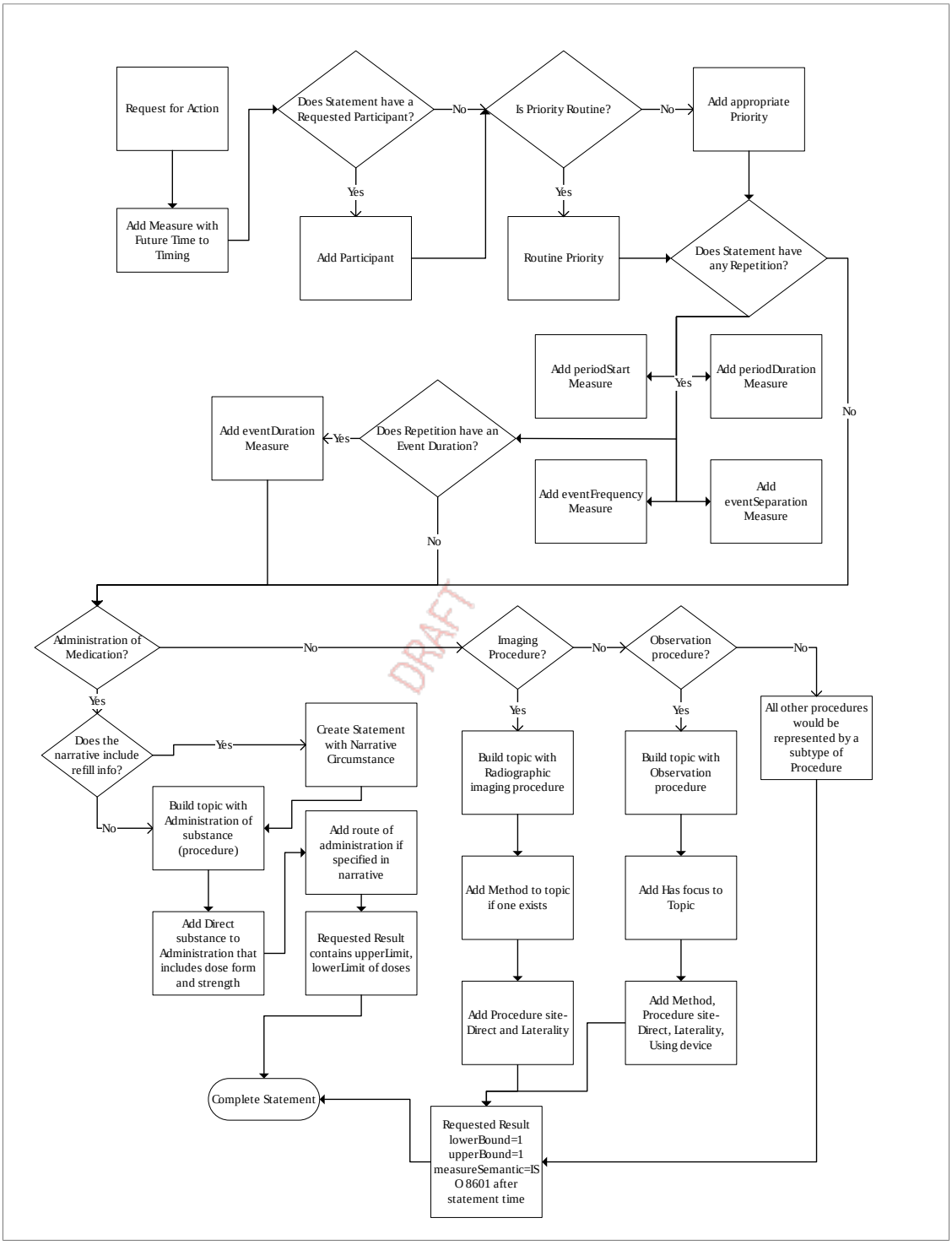


Figure 4.2. Request for Action Modeling Guideline Decision Tree

Timing: The Timing will always represent a future time in a Request for Action ANF Statement. Therefore, the Measure used in the Timing will be for a future time.

Editorial Rule 4.1. RequestedParticipant

If the Request for Action specifies a Requested Participant the requestedParticipant will be populated.

Priority: Priority is used to represent the priority for which the request is to be carried out. By default a Request will be considered "routine" unless otherwise specified.

Editorial Rule 4.2. Request for Action Topics

The topic follows a variety of possible patterns. For example:

- *Administration of Medication*: For requesting the administration of medication, the Topic will be built using the Administration of substance concept. If the narrative includes information about a refill, that information is currently represented as an Narrative Circumstance. All Administration of substance concepts will be refined with the substance and dose form and strength being requested. If Route of administration exists, then it will also be added.

- *Radiographic Imaging Procedure*: For requesting of imaging procedures, the Topic will be built using an Radiographic imaging procedure concept. These concepts will be further refined with a Method, Procedure site - Direct and (if appropriate) a laterality for those sites that are lateralizable.

- *Observation Procedure*: Any request for an action that is an observation would begin with an Observation procedure. The Observation procedure with then have a Has focus attribute linking it to the Clinical Finding or Disorder that it is being observed. The observation procedure can also be further refined by adding the Method, Procedure site - Direct, (if appropriate) Laterality, and Using device.

- *All Other Procedures*: Any other request for an action would be represented by a Procedure concept with any of the approved terminology procedure attributes applied.

Repetition: Repetition is used to represent when an action is requested for more than a single occurrence. Repetition is an optional component for a RequestCircumstance. A Request Component contains five Measures that are used to further define the parameters of the Repetition:

- *periodDuration:*This required field is used to represent how long a repetition should persist. If it is not specified, a default value of [0,inf) will be used. e.g. for 3 weeks

- *periodStart:* This required field is used to represent when a repeated action should begin. If it is not specified, a default value of [0,inf) will be used. e.g. NOW

- *eventSeparation:*This required field is used to represent how long between actions. If it is not specified, a default value of [0,inf) will be used. e.g. for 2 weeks

- *eventFrequency:*This required field is used to represent how often the action should occur. If it is not specified, a default value of [0,inf) will be used. e.g. 3 times per week

- *eventDuration:*This is an optional field that is used to represent how long every action should last.

Editorial Rule 4.3. requestedResult

If a requestedResult is not specified in the request, an upperBound and lowerBound of 1 is used with a MeasureSemantic of ISO 8601 after statement time. If a requestedResult is specified, the appropriate upperBound and lowerBound is specified with the correct MeasureSemantic.

4.4. Performance of Action Guidelines

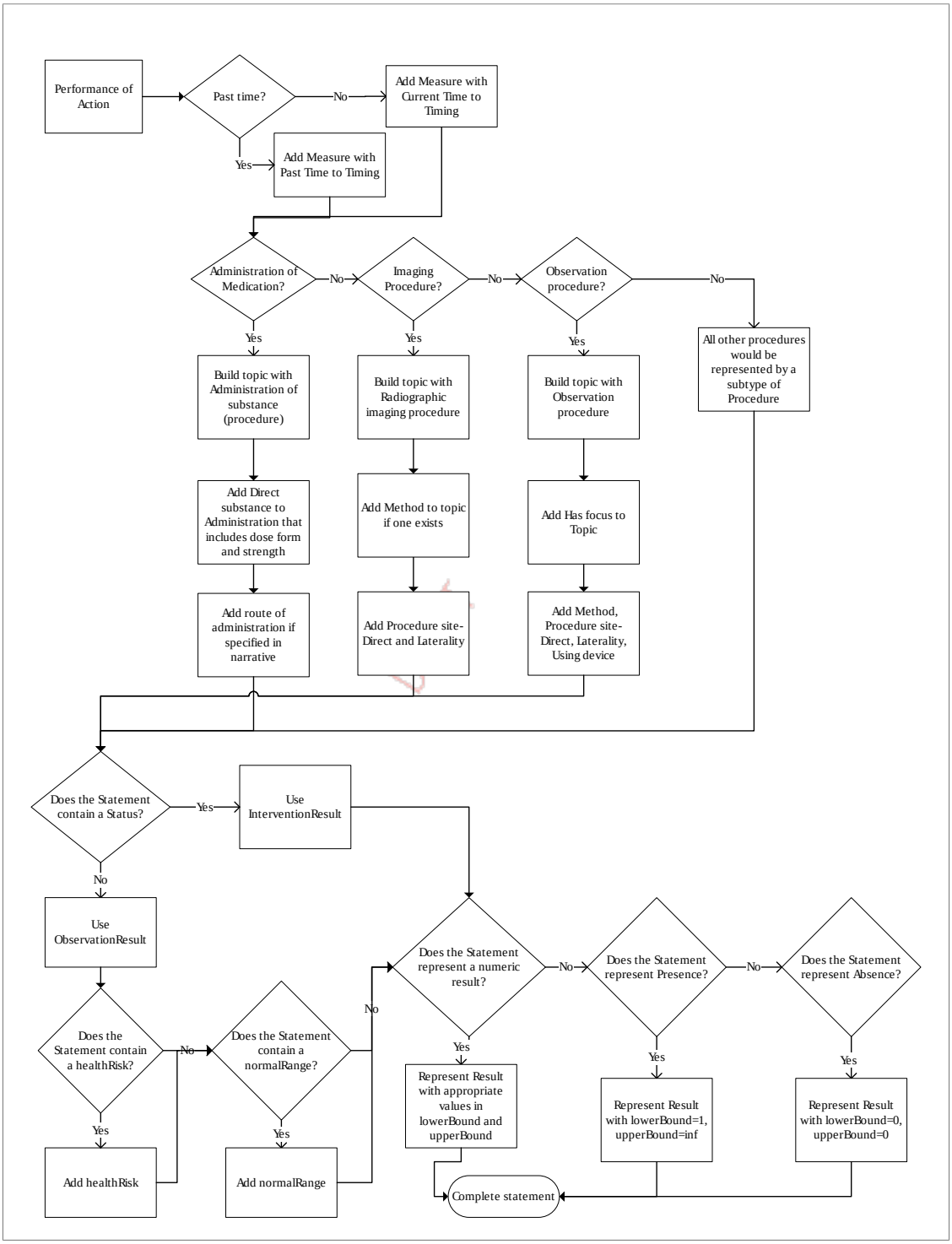


Figure 4.3. Performance of Action Modeling Guideline Decision Tree

Timing - Performance of Action: For a Performance of Action, the Timing can represent a time in the past or a current time. If a history of a performance of action is to be represented in ANF the Timing

will be for a time in the past prior to the statement. Otherwise the Timing will be represented by with the current time as of the statement.

Editorial Rule 4.4. Performance of Action Topics

The topic follows a variety of possible patterns:

- *Administration of Medication*: To represent the performance of an administration of medication, the Topic will be built using the Administration of substance concept. All Administration of substance concepts will be refined with the substance and dose form and strength being requested. If Route of administration exists, then it will also be added.
- *Radiographic Imaging Procedure*: For Performance of Imaging procedures, the Topic will be built using an Radiographic imaging procedure concept. These concepts will be further refined with a Method, Procedure site - Direct and (if appropriate) a laterality for those sites that are lateralizable.
- *Observation Procedure*: Any performance of an action that is an observation would begin with an Observation procedure. The Observation procedure with then have a Has focus attribute linking it to the Clinical Finding or Disorder that it is being observed. The observation procedure can also be further refined by adding the Method, Procedure site - Direct, (if appropriate) laterality, and Using device.
- *All Other Procedures*: Any other action that was performed would be represented by a Procedure concept with any of the approved terminology procedure attributes applied.

Editorial Rule 4.5. status

If the narrative being evaluated has a status (on hold, needed, rejected, etc) an InterventionResult will be used in order to record the status.

Editorial Rule 4.6. healthRisk

healthRisk is used to flag a result with coded values such as 'low', 'normal', high', and 'critical'.

Editorial Rule 4.7. normalRange

normalRange is used to represent the interval of values that are normal.

Editorial Rule 4.8. Result

If a Result is intended to represent a numeric result then the upperBound and lowerBound would be populated with the appropriate values. If a Result is intended to represent the presence of a Phenomenon, the Result will be represented with an upperBound and lowerBound of 1 and a MeasureSemantic of ISO 8601 current to statement time. If a Result is intended to represent the absence of a Phenomenon, the Result will be represented with an upperBound and lowerBound of 0 and a MeasureSemantic of ISO 8601 prior to statement time.

4.5. Editorial Rules

Editorial Rule 4.9. Performance versus request

Descrpription

Editorial Rule 4.10. Topics are always an action

- Observations are procedures concepts
- Medication administrations use an administration of subtance concept
- Laboratory procedures use Laboratory Procedure concept
- Imaging Procedures with use Imaging Procedure concept
- Administration of Medication Topic - Request for Action
- Request for Action Topics
- Performance of Action Topics

Editorial Rule 4.11. Timing - past, present, or future

Description

Editorial Rule 4.12. Results are always a ranged quantity

Description

Editorial Rule 4.13. Presence and absence are a countable quantity

Description

Editorial Rule 4.14. Separate compound topics

Description

Editorial Rule 4.15. Techniques are inseparable from the topic

Description

Editorial Rule 4.16. Prerequisites must be separated from the topic

Description

Editorial Rule 4.17. Related statements should be associated

Description

Editorial Rule 4.18. Subject of information is used to represent family and donor history

Description

Editorial Rule 4.19. Status indicates the state of result

Description

Editorial Rule 4.20. HealthRisk indicates the clinical risk of the result

Description

Editorial Rule 4.21. NormalRange indicates the normal range of the result

Description

Editorial Rule 4.22. Participants can be specified or requested

Description

Editorial Rule 4.23. Purpose indicates the purpose of a request

Description

Editorial Rule 4.24. Priority defaults to routine for a request

Description

Editorial Rule 4.25. Repetition is used to request multiple occurences of the topic

Description

Editorial Rule 4.26. A desired result can be part of a request

Description

5. Putting it Together: Normalization and Transformation

Normalization of *clinical statements* is defined as "the ability to identify every representational format that confers the same meaning as being equivalent (i.e., unambiguous representation). [Elkin_Terminology]

5.1. Data Structures

Currently, the standard is to define detailed clinical models using different data structures for different domains of clinical statements. For example, *FHIR* independently defines the resources for Conditions, Observations, Diagnosis, Procedure, Goal, Medication Administration, Medication Request, etc. Some implementations, such as FHIR, explicity define the property names for the parts of each data structure tree and other formalisms such as BMM/ADL and CEML use a form of key-value pairing to genericise the property naming of the data structure tree. But in all these cases, the fact remains that the resulting structure of the tree still remains different for different domains of clinical statements. Thus, computation and analysis of data instances, that conform to these models, requires a prior understanding of the tree structure for each domain.

ANF seeks to simplify the complexity that currently exists in detailed clinical models. As it's name suggests, Analysis Normal Form provides one normalized data structure to describe clinical statements from all domains. ANF accomplishes this by moving the complexity that usually requires a complex data structure into the terminology as a complex *post-coordinated* SNOMED CT expression.

5.2. Modeling Style

Another variation that currently exists is the allowed design choices which can be made by model authors. For example, a modeler may choose to model breath sounds, as 'breath sounds' with a coded result of 'rales', or as 'rales' with a result of 'present'. Currently, organiztions try to minimize this type of variation by documenting design choice rules in modeling "style guides". For instance, a common style guide choice in the *CIMI Clinical Statement* model is to either use the *Assertion* style or the *Evaluation Result* style, and *CIMI* documents which types of clinical statement are best suited for each. The current approach is to solve the problem by conformity rather than with technology.

ANF seeks to minimize this variation by only allowing quantitative results. This eliminates the choice between Evaluation style versus Assertion style clinical statements as coded results are not possible.

5.3. Transformation

The previous sections have described the variation that can exist in the data structure and modeling style of a single standard. Moreover, this variation is significantly compounded when simultaneously using data from multiple standards, such as when receiving data from mulitple institutions.

Analysis Normal Form can act as a transformation target to normalize these disparate representations of clinical statements, shown in Figure 5.1. Normalization implies the ability to recognize all representations that express the same meaning as being algorithmically equivalent.

To be clear, the transformation discussed is a data instance to data instance transformation. An example could be John Doe's Systolic Blood Pressure measurement taken on June 4, 2019 represented as a FHIR

Observation instance, which is then transformed to an ANF instance representing this same data. This is not to be confused with a detailed clinical model transformation between two formalisms, such as an *ISO DCM* for Systolic Blood Pressure transformed to a FHIR profile for Systolic Blood Pressure.

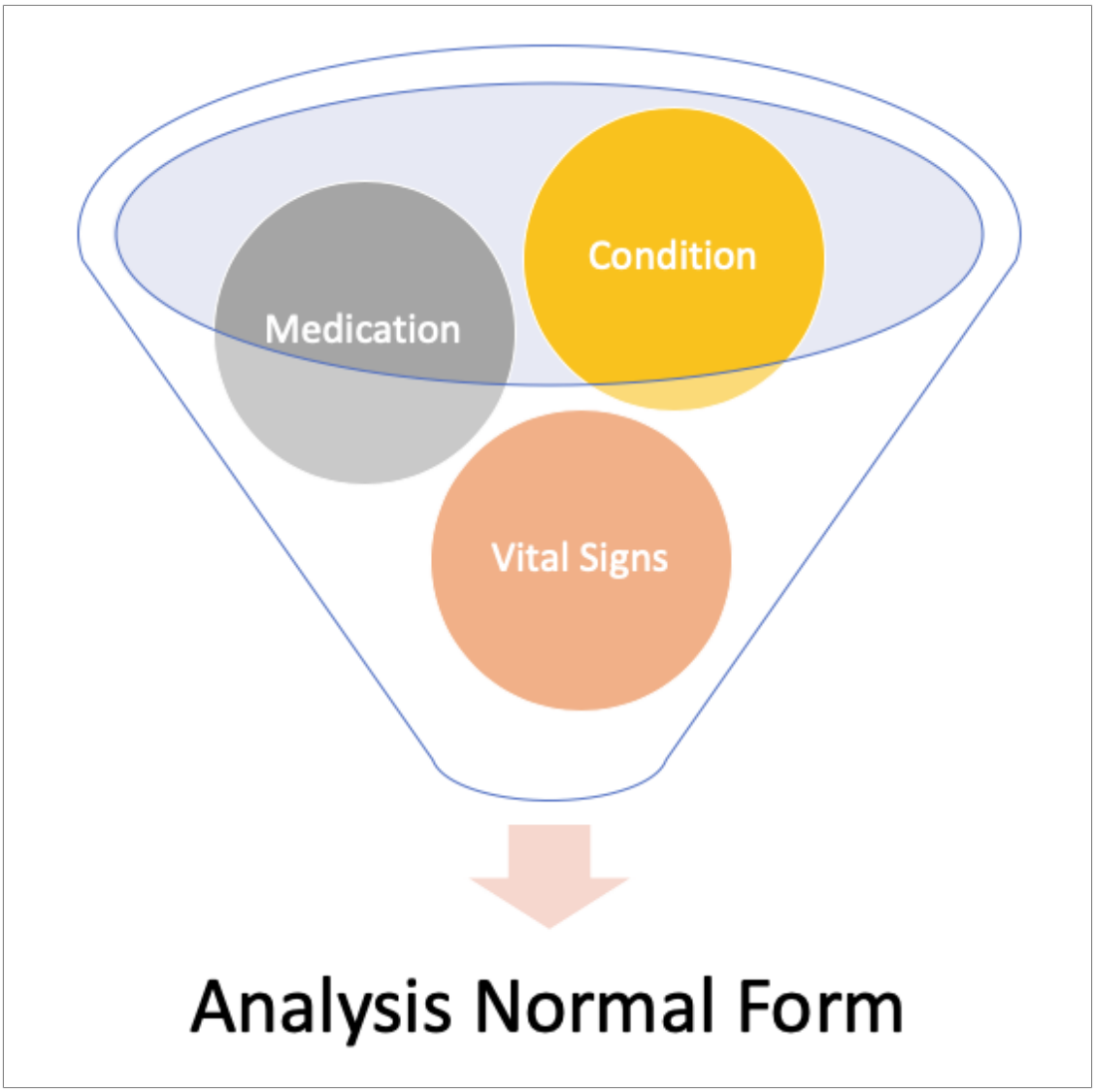


Figure 5.1. Transformation to ANF

Transformation, in this case, is not a simple endeavor that one can hope to automate across domains of clinical statements or even within a single domain of clinical statements. As presented, it will involve navigating disparate data structure trees and include variable representations to then generate a well-formed post-coordinated SNOMED CT expression. It is most likely possible to target subdomains for consistent transformation, such as all quantitative laboratory results, but in some cases, it may be that each detailed clinical model needs its own unique transformation.

Potential areas of difficulty during transformation

- One source instance will frequently be transformed to many ANF instances
- Implied clinical meaning of some data structure and bound terminology must be transformed into complex post-coordinated SNOMED CT expression for inclusion as *ANF Topic*

Currently, there are three basic categories of errors that might be associated with attempts at normalizing clinical statement represenation. The first is error associated with normalization of content of the terminology; the second is error associated with normalization of the semantics of the terminology; and, third are errors that result from ambiguous or misleading interaction between the structured clinical input and presentation of compound terminology to clinician end-users.

5.4. Transformation

A number of options exist for expressing transformation logic and for executing the transformation on specific instances of clinical data for normalization into ANF. These range from transformation languages to expensive middleware options commonly used in healthcare interfaces. The suitability of the chosen language highly depends on the format of the source data, and the quality and accuracy of the transformation is left to the transformation author. One option described here is Model Driven Message Interoperability (MDMI), which is an architecture for transformation that assists in producing semantically accurate transformations.

5.4.1. XSLT

XSLT is a W3C-standard language for the transformation of structured data. [xslt] XSLT transformation scripts take as input any valid XML document and produce as output an ASCII-formatted document (including XML, HTML, other formatting languages, free text, etc.). The XSLT language specifies transformations through declarative, rule-based commands (see below).

XSLT is widely used in modern information processing, including in health care applications. Numerous XSLT transformation engines exist, including commercial and open-source versions. These implementations are mature, stable, and high-performance, and are available as runtime libraries or embedded in XLST authoring/editing applications. Excellent documentation and training are available for XSLT.

5.4.1.1. Overview of Language and Data Model

XSLT scripts operate over source “trees” containing the structured contents of parsed XML documents. These trees contain as their nodes the various constructs of specific XML documents, i.e., the named elements, attributes, and text values that appear in the documents, and upon parsing, becomes a source tree for XSLT transformations.

XSLT uses the sub-language “XPath” to reference portions of the XML source tree for purposes of navigating the tree and selecting specific parts of it to translate. [xpath]XPath is essentially a query language for identifying and retrieving XML sub-trees that match specified criteria. For example, the XPath query

The actual transformation logic in XLST scripts is specified as a series of “templates”. Each template matches to a specified sub-part of the source tree and specifies what output will be generated for that sub-part. Templates are generally called from within other templates via a declarative template-matching process, and a recursive traversal and transformation of the input tree occurs through this template-invocation model. The transformation logic within templates may include various conditional, branching, and formatting constructs, as well as calls to external functions written in various programming languages (such as Java).

5.4.1.2. Advantages and Limitations

XSLT is effective in representing and executing the transformation logic needed for clinical translations. In general, XSLT provides various advantages, as well as limitations, for this task.

Advantages

- A powerful language
- Declarative – automated matching of templates to data
- Extensible via extension functions and external function calls
- Many mature implementations
- Good tooling (e.g., Eclipse plugin, XMLSpy)
- Good documentation

Limitations

- Transformation specifications are verbose and hard to read/understand/debug/maintain
- Transformation are entirely syntactic
- Limited to XML input – instances rendered in other formats cannot be translated

5.4.2. FHIR Mapping Language

The FHIR mapping language (FML) [FML] is a relatively new, bespoke transformation language specifically designed to transform HL7 FHIR resources to alternative representations, including different FHIR resources, C/CDE documents, etc. [fhir] The mapping language was created by Graham Grieve as a specification of the QVT framework for model-transformation languages (see Section 5.4.3, “QVT”).

5.4.2.1. Overview of Language and Data Model

Conceptually, FML is similar to XSLT in that it (a) consists of declarative rules that are automatically matched to input data, (b) includes a sub-language (“FHIRPath”) to reference parts of source parse trees, and (c) has the ability to reference external functions written in different languages. There are also notable differences between FML and XSLT. The source input of FML is not limited to XML documents, but may include any object models and rendering syntaxes conformant with *OMG’s Meta Object Facility (MOF)* language. [mof] MOF is a general formalism for representing object models as directed acyclic graphs (DAGs), and MOF-compliant models can use various syntactic constructs to represent the classes, attributes, and attribute values of such graphs.

Hence, in FML, there is no built-in notion of source trees containing XML “elements”, “attributes”, “comments”, “namespaces”, etc. In fact, FML transformation rules do not specify any target syntax for inputs or outputs, just the general concepts of named classes, class members, and member values. This flexibility would allow transformation source inputs used in the normalization to ANF to be represented in different formats than XML, were that to be deemed preferable. For example, instances rendered using JSON, ODIN, or ASN1 syntax could be the inputs of FML transformations.

The output of an FML transformation is not a text-rendered document (unlike XSLT), but an internally stored DAG consistent with the specified output model. Subsequently, the DAG may be rendered in any number of syntaxes, including XML, JSON, or the tables and fields of a relational database.

5.4.2.2. Advantages and Limitations

The FHIR Mapping Language may also be effective in representing and executing the transformation logic needed for normalization to ANF. As with XSLT, however, there exist certain trade-offs in its use.

Advantages

- Support for input formats other than XML
- Transformation logic produces semantic DAGs, which can be subsequently rendered in a variety of syntaxes.

- The mapping specifications are more concise and easier to read/understand than XLST

Limitations

- Inputs/outputs other than FHIR *logical models* currently require additional custom programming
- Only XML and JSON are currently supported as output syntaxes without custom programming
- Only one implementation to date (as a library)
- Limited tools for authoring/editing transformation scripts
- Limited sources of documentation
- Few knowledgeable programmers

5.4.3. QVT

A third alternative is to develop a new transformation language customized to support the requirements of a normalization to ANF, based on the QVT language used to develop the FHIR Mapping Language.

5.4.3.1. Overview

QVT [qvt] is a general model-transformation framework and language developed by the Object Management Group . It includes both an imperative ("QVT-O") and a declarative ("QVT-R") version, and offers considerable flexibility in defining the constructs of purpose-specific transformation languages. Although QVT is intended for the transformation of data *models* rather than data instances, the FHIR Mapping Language shows that it can be applied to the latter task as well.

A number of implementations of QVT exist as open-source and commercial software offerings. These include:

- ATL (open source). Probably the most widely used and maintained of the available implementations. Includes a library of existing QVT transformations, to serve as examples and templates.
- Eclipse M2M Project (open source). An Eclipse project that includes authoring tools for QVT transformations, as well as various transformation engines (including the one from ATL).
- ModelMorf (proprietary)
- Others (see [qvt])

5.4.3.2. Advantages and Limitations

The strength of QVT is that it is very abstract, which confers great flexibility and configurability to create custom transformation languages. However, the abstractness also makes QVT quite difficult to understand and learn, and there are limited resources to assist in the learning process. For example, a search on Amazon Books for references on the QVT framework yielded only 8 relevant results, most of which were not in English. In contrast, a similar search for XSLT references returned 270 results.

5.4.4. Model Driven Message Interoperability (MDMI)

MDMI is an Object Management Group Standard for the transformation of data in one format to data in another format. MDMI Standard is not a language. The MDMI Standard is a specification for addressing this problem and was developed by multiple domain experts. The specification contains two major sections: the MDMI Transformation Metamodel and the MDMI Semantic Element Exchange Repository (SEER).

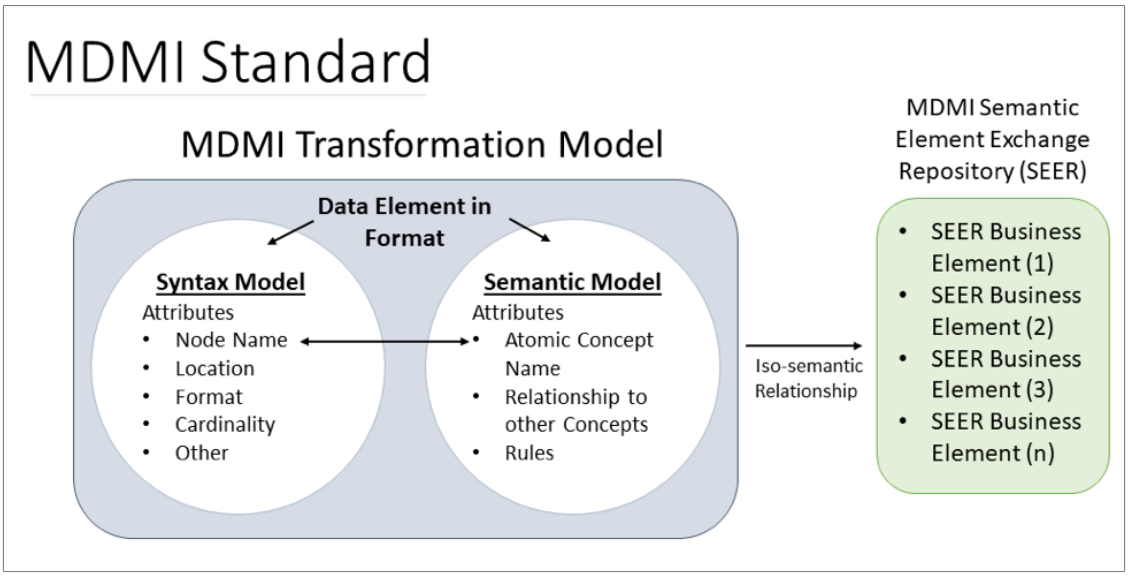


Figure 5.2. MDMI Standard

The MDMI Transformation Metamodel is composed of a syntax model and a semantic model. The syntax model contains the syntactical representation of each data element in a format and the semantic model contains the semantic concept represented by the data element. The syntax model is used to compose a collection of semantic representations into a target file format or to decompose a source file into its semantic representations. The syntax model can be used for any format. XML, JSON, HL7 V.2, CVS, various EDI payment, and proprietary formats have been used.

The semantic model captures the semantic concepts in the format and the relationships between the semantic concepts in a format. Probably the most important relationship is the containership relationships. The semantic model of the MDMI is also used to capture other relationships and rules required to create unambiguous semantic representations. An example of this is a data element that can have multiple semantics concepts that must be disambiguated based on other values contained in format.

The MDMI SEER is a repository for the semantically unique concepts, called Business Elements, that are exchanged in healthcare transformations. One can view the MDMI SEER as a bag of unique, atomic semantic concepts exchanged, primarily driven by the *HL7 standards of v.2*, *CDA*, and FHIR that are used to exchange information. If there is a new semantic concept that does not exist in the SEER, then a new Business Element is simply added. Each MDMI Transformation Model uses the MDMI SEER to create an iso-semantic relationship with its own semantic concepts and a Business Element.

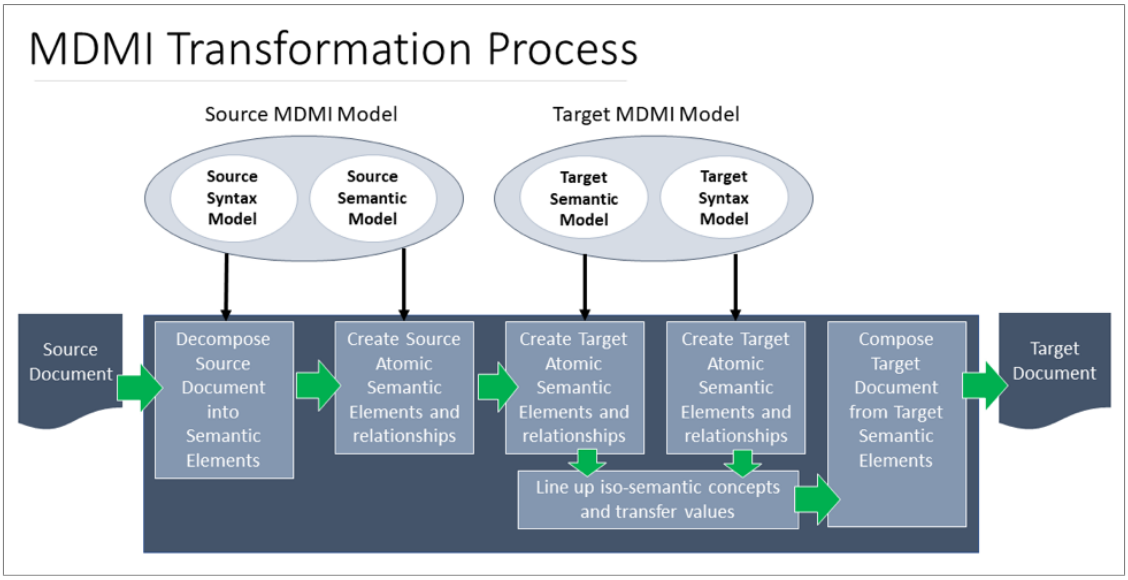


Figure 5.3. MDMI Transformation Process

There is a project underway in the OMG to extend the MDMI SEER. The Business Elements in the MDMI SEER are *pre-coordinated semantic concepts* represented in industry standard healthcare ontologies and terminologies. The project is using the ANF Clinical Statement Model as a Reference Model to develop a semantic model that can precisely define the meaning of the Business Element in a detailed, structured, unambiguous, computable formalism.

An open source implementation of MDMI started in the Open Healthcare Tools organization which built an MDMI compliant tooling for healthcare. The MDMI Open Source Project continues today in GitHub and has been and is being used in HL7 projects as well as in commercial implementations.

5.4.5. Advantages and Limitations

MDMI is a model driven approach. Having a formal model, the open source project has been able to develop tooling based on the MDMI model as well as leverage other modeling efforts. Examples are Information Models such as FHIR and the FHIM using the model driven MDHT tooling and Ontological Models such as ANF / *Solor*.

Advantages

- Any to Any transformations versus point to point language mappings allow reuse of transformation models for different use cases.
- It minimizes change. If one MDMI Model changes (e.g. FHIR 4 to FHIR 5), this does not require changes to other existing MDMI Models such as CCDA 2.1, HL7 V2.8, or a proprietary model.
- It simplifies development. Tooling exists to develop and maintain individual MDMI Models by SMEs who do not need to be developers. The scope of expertise is further reduced because the knowledge one needs to create a MDMI Model is primary to know what the data in their format means.
- It enables automation tooling for creating MDMI models, for creating computable artifacts, and generating reports.
- There are Open Source Models for HL7 formats as well as the MDMI tooling.

Limitations

- MDMI has limited experience with transformations of detailed clinical models.
- User Documentation of MDMI is lacking.

- The MDMI runtime tool is complex.

6. Pragmatic Usage and Next Steps

Like other CIMI isosemantic models, ANF is a logical model and therefore it may implemented using relevant implementable models and technology (see SAIF-CD). Therefore, this project will expand on the use of ANF alongside preexisting information exchange HL7 standards (i.e. HL7 V2 messaging, CDA documents) and HL7 standards-based APIs (i.e., FHIR resources). In practice, ANF is applicable to systems normalizing or creating normalized data to support Assertional and Procedural knowledge (e.g. clinical alerts, workflow, data analysis, decision support). These need to aggregate data from many isosemantic source models into a single analysis format.

Implementers may use the logical model and methodology in this document to design software components, databases, or APIs that support reuse and analysis of treatment information captured using best practices (e.g. CIMI models) and exchanged using interoperability specifications required across the US (e.g. FHIR US Core, Consolidated CDA). Since information sharing already relies on a variety of clinical statement approaches and syntax representations, it will become necessary to create normalized instances of those clinical statements intended for reuse. Not all the data produced by a system is necessary for analysis; and, the ANF model - like other CIMI models - is focused on clinical information. ANF does not require a specific input form syntax , its focus is on implementations where data quality and semantics and information is aggregated from many and diverse sources.

The ANF logical model can be used to create practical implementation guidance (i.e. implementation guide, profiles, value sets based on standard terminology) and can be applied to design data analysis solutions. Implementation specifications include provide vocabulary binding based on standard terminologies (e.g. SNOMED CT, LOINC, RxNorm) to support the Terminology layer of the Knowledge Architecture.

6.1. ANF FHIR implementation

ANF is a logical model intended to represent any clinical data using a complete yet simple normal form. It allows other software modules to reuse the information and derive new knowledge from it. Examples of ANF's benefits include improved ability to (1) analyze the care that was delivered, (2) find out what type care leads to the best patient outcomes, and (3) use rules and business triggers to automate clinical decision and workflow steps. ANF could be used to design standards-based Application Programming Interfaces (APIs) optimized for a specific analysis purpose. ANF APIs may be implemented using FHIR resources, profiles, and extensions to access clinical decision support, clinical quality measures, and to support workflow automation by triggering reminders and clinical notifications.

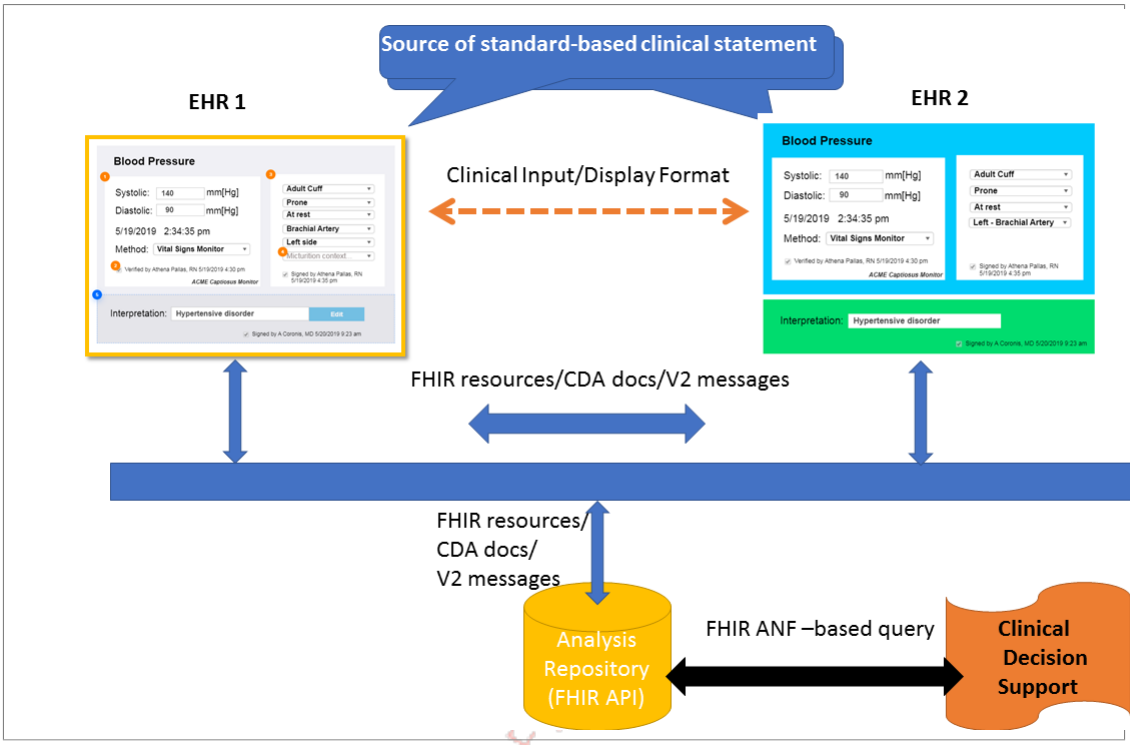
ANF statements may be created from existing clinical statements and patient-entered data to support APIs intended for Analysis or to automate information derived from device measurements, clinician inputs, and patient-generated data:

6.1.1. Analysis API

The typical implementation of ANF will be a system that normalizes clinical information (e.g. FHIR, CDA documents) to be used by business and decision support rules. Healthcare enterprises may use middleware, standards-based transformation and terminology servers to normalize a variety of observations, orders, diagnoses, medications, procedure notes, and other interventions to a set of Performance or Request statements. Narrative clinical statements may not be immediately reducible to ANF and it may require natural language processing and other methods of augmentation and enhancement.

ANF-specific resources and implementation guidance can be tested during FHIR Connectathons to validate that the logical model outlined in this specification is suitable to data aggregation and supports the analysis

objectives of researchers, before proposing them as new resources for future versions of FHIR and as extensions and profiles for current versions. Both approaches may be desirable.

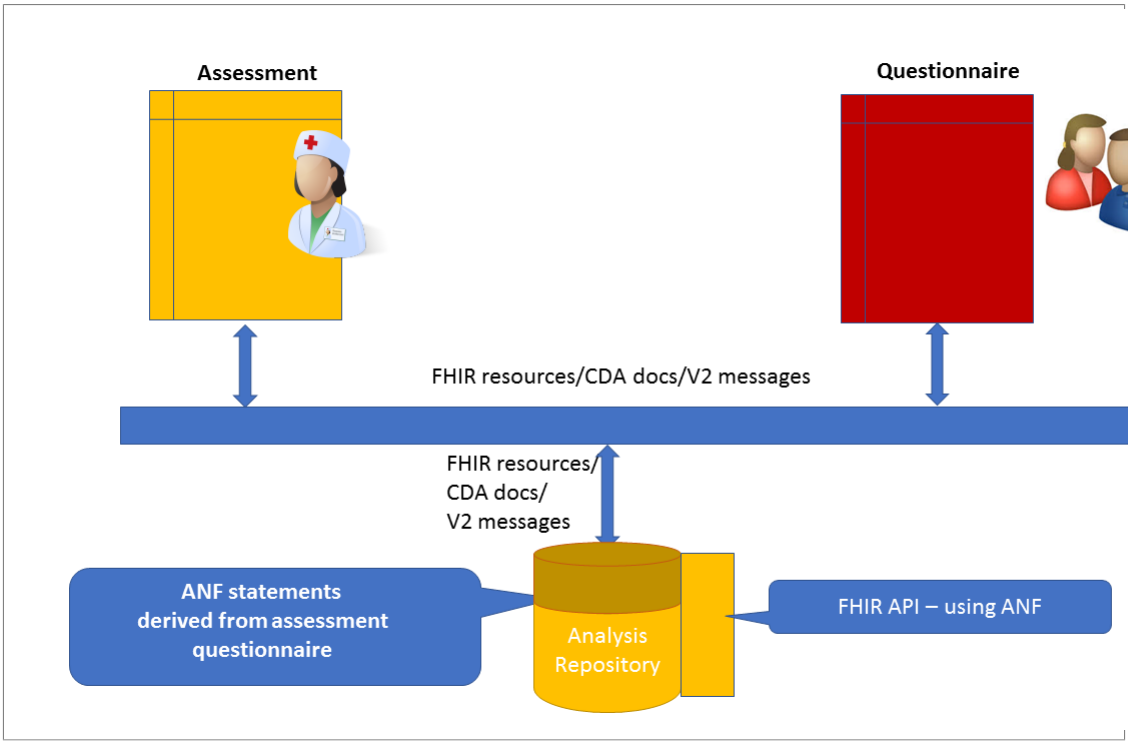


ANF-based information can be used to create data warehouses and support data mining.

Figure 6.1. ANF-based FHIR API

6.1.2. Automated Data Analysis

ANF statements may be created as an outcome of evaluating device, clinician, patient-entered data (e.g. questionnaires) automatically and in near-real-time. For example, specific answers to a PHQ-9 screening tool along with previous assessments could trigger a specific type of follow-up screening regarding substance use treatment or further evaluation, consideration of Social Determinants of Health, or alert to a provider. While ANF statements are not intended as an input form, such statements could be automatically generated by learning EHR systems [ehr] using on a combination of pre-existing clinical data, clinical guidelines/rules, medical device observation and patient-generated data. The promise of the Learning EHR system [ehr] is the ability to learn new knowledge from previous clinical statements and latest scientific developments. This approach also conducive to tailoring treatment consistent with Precision Medicine [cancer] and reducing provider burden through automation.

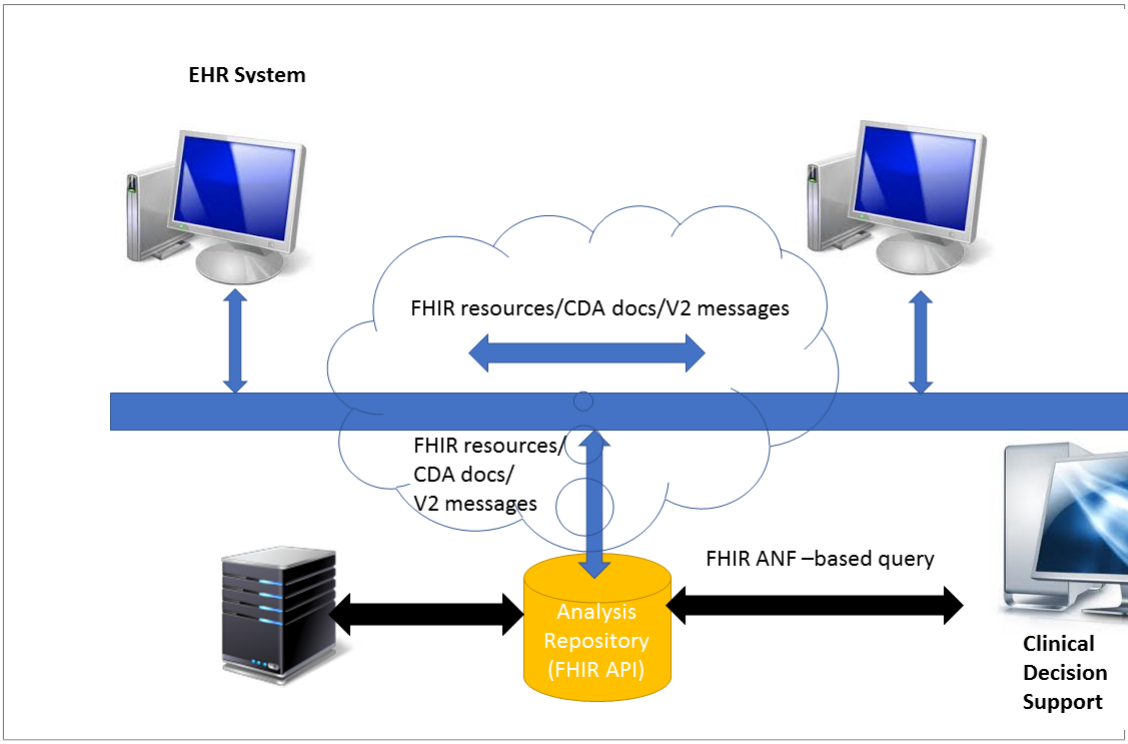


ANF statements may be derived from other data inputs and combined to support near-real-time analysis.

Figure 6.2. ANF-based FHIR API

6.2. Other platforms

Big data analytic, data mining, business intelligence, healthcare quality programs, registries etc. all require large data sets of consistent structure and semantics that can be analysed I aggregated for the benefit of individual patients, to evaluate an organization, or to establish new facts.



Standard-based information may be normalized to ANF to be used for clinical decision support.

Figure 6.3. ANF-based FHIR API

Interoperability standards sometimes pose challenges due to the use of synthetics/abstract data types that attempt to capture the complexity of healthcare data. ANF simplifies the statement structure by using a small set of primitive types (e.g. float, varchar, boolean) and a sophisticated terminology . Data warehousing and mining solutions rely need a consistent simple representation of data organized along facts and axes. ANF borrows from Database Normalization the idea that "normalization" to reduce data redundancy and improve integrity. The ANF logical be used to design database "fact based" dimensional schemas that enable analysis focused on a specific set of facts and dimensions to evaluate outcomes associated with the use of a specific therapy, device, or medication. .

7. Implications - Improving Patient Safety and Outcomes

ANF has implications on clinical data quality, clinical decision support, patient safety and population health because it promotes the reuse of information aggregated to derive new information about treatment quality, patient safety, and outcomes.

7.1. Implications for Data Quality

Information systems record and manage clinical statements using a variety of standard or ad-hoc models and formats. However, both treatment and analysis of clinical statements require consistency not only at the format level (e.g. CDA, FHIR, V2) but also the content and semantics (i.e. ANF, CIMI model, etc.). In most cases the data quality is the greatest obstacle to analysis. Analysis Normal Form aims to minimize data quality challenges and provide a common format with semantic clarity to allow for a meaningful secondary uses of clinical data.

The design of ANF is based on research into data quality frameworks [Kahn] that identified that information conformance, completeness, and plausibility are all necessary to analysis.

- **Conformance**: Conformance how well a system or implementation meets a specification. ANF provides a logical structure and constraints of clinical data for value conformance, relational conformance, and computational conformance irrespective of data representation (e.g. CDA, FHIR)
    - Value Conformance: Value conformance seeks to determine if recorded data elements are in agreement with a predefined, constraint-driven data architecture. Internal data constraints are typically imposed by the ANF Reference Model
    - Relational Conformance: Relational conformance seeks to determine if the recorded data elements are in agreement with additional information referenced by a clinical statement. An ANF Statement may reference other information about patients, practitioners, encounters, etc. to provide context to the topic and result recorded.
    - Computational Conformance: Computational conformance seeks to determine if computations used to create derived values from existing variables yield the intended results either within a data set (Verification) or between data sets (Validation), when programs are based on identical specifications. Computational conformance focuses on the correctness of the output value of calculations against technical functional specifications. ANF highlights the measure in which a an action, finding, or observation was either requested or performed to a common "measure" thus supporting the development of computational, assertional, and procedural predicates.
- **Completeness**: Completeness focuses on features that describe the frequencies of data attributes present in a data set without reference to data values. Completeness measures assess the absence of data at a single moment over time or when measured at multiple moments over time. ANF disambiguates the date a statement was made/asserted from the timing of the circumstances in which the underlying action, observation, or finding.
- **Plausibility:** Plausibility focuses on features that describe the believability or truthfulness of data values. For this category, plausibility is determined by a variable's value, when a value is placed within the context of another variable (i.e., two independent variables assessing the same construct), or a temporal sequence or state transition (e.g., patient follow-up treatment for a disease must be preceded by a corresponding diagnosis).

- Uniqueness Plausibility**:** The Uniqueness subcategory seeks to determine if objects (entities, observations, facts) appear multiple times in settings where they should not be duplicated or cannot be distinguished within a database (Verification) or when compared with an external reference (Validation). Duplication frequently occurs when disparate data streams that contain overlapping objects are combined. ANF provides the contextual data needed to de-duplicate clinical statement prior to analysis.

- Atemporal Plausibility: Atemporal Plausibility seeks to determine if observed data values, distributions, or densities agree with local or “common” knowledge (Verification) or from comparisons with external sources that are deemed to be trusted or relative gold standards (Validation). For example, in the case of systolic blood pressure, an independent verification of the value measured by a device is provided by the practitioner who conducts performance. ANF clinical statements support results that evaluated based on a "reference range" of plausible values based on patient status, device-supported ranges, or human physiology.

- Temporal Plausibility: Temporal plausibility seeks to determine if time-varying variables change values as expected based on known temporal properties or across one or more external comparators or gold standards. Temporal properties that establish expectations in this subcategory include temporal stability (do values vary over time as expected), temporal continuity (do values persist over time as expected), state transitions (do sequences of events occur as expected), and temporal dependencies between time-varying variables.

7.2. Implications on Clinical Decision Support

A 2012 Literature Review commissioned by the Agency for Healthcare Research and Quality (AHRQ) found evidence showing that CDS had positive impact on process measures and increasing user knowledge relevant to a medical condition. [ONC]

Additional studies show that well-executed CDS can [ONC] :

- reduce adverse drug-drug interaction events and medication errors;

- decrease unnecessary lab testing;

- reduce cardiovascular risk in patients with type 2 diabetes;

- improve practitioner performance;

- increase cardiovascular disease risk assessment in routine primary care practice;

- improve public health outcomes associated with outbreaks of food-borne illness;

- and, produce cost savings associated with hospital-based pharmacy interventions.

Taken together, the available evidence shows that CDS —when implemented in the right context, and when governed with formal management—can reduce errors, improve the quality of care, reduce cost, and ease the cognitive burden on health care providers. [ONC] As a result, the impetus for achieving standardized, widespread adoption of CDS across health systems is clear.

A report entitled “*Optimizing Strategies for Clinical Decision Support: Summary of a Meeting Series*” [ONC] was produced out of the collaboration between the ONC and the National Academy of Medicine (NAM). The report states that there are at least four important technical challenges to sharing and therefore standardizing implementations of CDS content: [ONC]

(1) insufficient standardization of patient data representation;

(2) insufficient standardization of CDS knowledge representation;

(3) insufficient standardization of CDS integration mechanisms;

(4) a need to align with broader standardization initiatives.

One of the reasons that CDS interventions are difficult to implement between health care systems is because disparate EHR systems and health care systems utilize different underlying patient data models and clinical statement representation mechanisms. Even distinct instantiations of use of the same EHR systems differ in how they encode patient data and in how they represent clinical statements. The ONC and NAM report states that "[b]ecause CDS relies on inferencing using patient data, this heterogeneity in patient data representation poses an immense obstacle to sharing CDS." [ONC]

ANF aims to reduce the variability of clincial data inputted into EHR systems and modeled/stored in data repositories. The standardization of clinical observations in a manner that supports automated processing requires a formal clinical statement model, such as ANF. The most important requirements of such a statement model are that (1) it can represent any clinician-specified observation accurately and precisely and (2) it can support automated query and retrieval operations correctly and efficiently.

ANF aims to reduce the variability of how clinical data within the value sets and clinical decision rules managed by EHR systems and modeled/stored in data repositories. For example, a clinician could document that a patient has “bacterial pneumonia caused by methicillin-resistant Staph. Aureus” by combining the pre-existing concept “bacterial pneumonia” with the pre-existing concept “Methicillin Resistant Staph. Aureus” and specifying that the latter is the “causative agent” of the former. The patient’s medical record would then contain an entry consisting of the following expression:

Bacterial Pneumonia (ConceptID = 53084003) : Causative Agent (ConceptID=246075003) = Methicillin Resistant Staph. Aureus (ConceptID=115329001)

If specified correctly, post-coordinated expressions also support subsumption testing. Hence, the patient whose record contains the expression above would also be identified by the query “find all patients with a diagnosis of any infectious disease (Infectious Disease : ConceptID = 40733004) in their record.”

7.3. Implications on Population Health

Electronic clinical quality measures (eCQMs) and CDS alerts are triggered by clinical data that is represented in data repositories by clinical statements represented by detailed clinical models with data elements encoded by standards-based clinical terminologies. Because these measures and alerts intend to promote evidence-based clinical processes, variations in clinical data caused by having inaccurate, incomplete, or antiquated implementations of underlying logical models may impact the ability of clinicians to assess care and improve quality. Jean-Jacques et al. showed that health information technology-supported quality improvement (QI) initiatives can decrease disparities for some chronic disease management and preventive measures QI.[Jean] Data-driven QI efforts rely heavily on patient-level data generated by eCQM reports or CDS alerts, which are dependent upon standards-based encoded clinical data. If clinicians rely on inaccurate implementations of eCQMs and CDS, then they may have lists/alerts with patients intended to be excluded from a measure/alert, and may therefore, target inappropriate patients for therapies, such as recommending aspirin use for someone at high-risk for a fatal bleeding event. Similarly, life-saving treatment may be denied or delayed.

Implementation reasearch shows that variations in implementations of eCQM specifications for cardiovascular event prevention could result in potential lives saved or harms avoided in quality improvement activities [Cholan_specs] . For aspirin use for secondary prevention of heart attacks, Number-Needed-to-Treat (NNT) statistics show that of patients with known cardiovascular risk who took aspirin, 1.3% were helped by preventing a non-fatal heart attack, and 0.25% were harmed by a major bleeding event. An implementation study [Cholan_specs] against clinical data from two primary care clinics shows that 121

(92%) of the patients were inappropriately included in a measure's denominator. These patients were also taking an anticoagulant medication, so the Number-Needed-to-Harm (NNH) statistic for this subset of patients for aspirin usage is likely much higher, and for this study, 1 to 2 people may have been harmed if the inaccurate implementation persisted, as evidence shows that patients with combinations of aspirin, warfarin, and clopidogrel are associated with up to a three-fold higher risk of bleeding for patients on dual therapy and triple therapy. With another measure for statin therapy, 1 in 21 people have a repeat heart attack, stroke or death avoided, so even 10 missed people have significant risk of events. Similarly, 10% are harmed by muscle damage or pain, or ~1 of the 14 inappropriately included in the study. [Cholan_specs] Even in the small eCQM implementation study [Cholan_specs] with data from two primary care clinics, failure to include or exclude patients could have led to real harm.

With eCQM implementation and QI infrastructure increasing, the problem of having, and using, inaccurate eCQM implementations or CDS implementations could have significant potential negative impact on population health by not avoiding events and avoiding harms for patients. ANF reduces these erroneous implementations. Without a precise logical model for clinical data like ANF, comparability of eCQMs for payment programs and utility of CQM data for targeted quality improvement may be limited.

7.4. Summary

In conclusion, Analysis Normal Form (ANF) presents a simple reproducible approach to modeling clinical statements specifically for data analysis. It reduces clinical statements to two types, Performance of an action, finding, or observation and Request for Action, both clinical statement types with topics. ANF is compatible with other work in statement representation models such as the CIMI Clinical Statement approach, with its focus on more traditional complex structured trees, whereas ANF focuses on structuring data in a way CDS systems can extract data in an unambiguous way. ANF provides a single, normatlized, form for clinical statements that may be used to create assertional or prcoedural knowledge articacts as clinical decision support

8. Acknowledgements

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- Walter Sujansky[5]
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[2]Deloitte Consulting LLP

[3]Book Zurman, Inc

[4]HL7 CIMI Work Group

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Complete Glossary

ANF (Analysis Normal Form)	An approach to clinical statements that ensures the statement representation is reproducible and scalable, with the adherence to principles of being simple, reproducible, and use case driven, with immutability and no false dichotomies.
ANF Circumstance	ANF Circumstance is a property of ANF Statemment with a value representing the HOW, WHY, WHEN, and with what RESULT a requested or performed action will be or was carried out.
ANF Performance	An ANF Performance is an instance of an ANF Statement that represents the performance of an action.
ANF Request	An ANF Request is an instance of an ANF Statement that represents the request of an action.
ANF Statement	An ANF Statement is a technology construct used to represent an instance of a clinical statement as defined by the Analysis Normal Form specification.
ANF Topic	A property of ANF Statemment with a value of a Logical Expression representing WHAT is being requested or what was performed
Architectural Foundation	The Architectural Foundation of the Knowledge Architecture provides the common elements of interoperability such as object identity, versioning, modularity, and knowledge representation. It includes a) the foundation and building blocks of the common model; (b) how the repeatable transformation process of disparate standards into the common model promotes interoperability with other environments; and (c) how the modules of the architecture are tightly version controlled over time.
Assertion	Assertion is a design pattern to represent a clinical statement in a form which specifies what is being asserted paired with a form of presence or absence. Examples would include 'Rales are present' and 'Diabetes is not present'.
Assertional Knowledge	
Category	
CIMI Clinical Statement	A CIMI Clinical Statement is a technology construct defined by the HL7 CIMI working group used to represent an instance of a clinical statement.
CDS (Clinical Decision Support)	A function for electronic health records systems designed to help sift through large amounts of electronic health data to suggest next steps for treatments, alert providers to available information they may not have seen, or catch potential problems, such as dangerous medication interaction.
CIMI Model (Clinical Information Model)	A representation of the structured clinical information (including relationships, constraints and terminology), that describes a specific clinical concept - e.g. a blood pressure observation, a Discharge Summary, or a Medication Order.
CIMI (Clinical Information Modeling Initiative)	A workgroup of Health Level 7 (HL7) focused on improving the interoperability of healthcare systems through shared implementable clinical information models, and a sponsor of this whitepaper. For more information please see http://www.hl7.org/Special/Committees/cimi/index.cfm

Clinical phenomenom	___ TBD ____
Clinical Statement	A clinical statement is a general informatics term. It is a definite and clear representation of a clinically-significant fact or situation that was observed to exist or happen. See Also Statement, Statement Narrative.
CIM (Computationally Independent Model)	___ TBD ____
Constraint Model	A model which constrains or limits the allowable values of a reference model, or further constrains another constraint model.
Context expression	The ‘context’ describes the circumstances that form the setting in which the ‘topic’ should be evaluated.
DCM (Detailed Clinical Model)	A detailed clinical model is a general informatics term. As it's name suggests, it is a model that describes the fine details of specific clinical information. For example, a detailed clinical model representing a systolic blood pressure measurement would describe allowable body locations to take this measurement and the allowable units of measure. Thus, a detailed clinical model for systolic blood pressure would disallow the nonsensical clinical statement of "A systolic blood pressure taken on the femur with a result of 3 inches".
DAM (Domain Analysis Model)	
DE (Domain Expert)	
Editorial Rule	as a rule to aid in the proper modeling of an ANF Statement instance.
Evaluation Result	Evaluation Result is a design pattern to represent a clinical statement in a form which specifies what is being evaluated paired with the result of that evaluation. Examples would include 'Heart Rate = 80 bpm' and 'Breath sounds = rales'.
FHIR (Fast Healthcare Interoperability Resource)	A HL7 interoperability specification for the exchange of healthcare information electronically
HL7 (Health Level Seven)	
HRO (High Reliability Organization)	Organizations characterized by high levels of safety under inherently risky, technologically-complex, and demanding conditions.
CDS Workgroup (HL7 Clinical Decision Support Workgroup)	A workgroup of Health Level 7 (HL7) that focuses on development of standards to support system-agnostic implementations of clinical decision support, including messages, services, information models, and knowledge representation formalisms. For more information please see http://www.hl7.org/Special/committees/dss/index.cfm.
CDA (HL7 Clinical Document Architecture)	an XML-based markup standard intended to specify the encoding, structure and semantics of clinical documents for exchange.
HL7 Service	Aware Interoperability Framework Canonical Definition (SAIF-CD) – HL7 introduced an architecture to allow for a clear separation of concerns among interoperability models and specification from the abstract or conceptual to the most precise, implementable, and testable that ensures semantic interoperability. [SAIF-CD] defines three SAIF Perspectives: Conceptual, Logical, and Implementable.

HL7 V2 Messaging Profile	HL7's Version 2.x (V2) messaging standard is widely used for electronic data exchange in the clinical domain. This messaging standard allows the exchange of clinical data between systems.
HL7 V3	A suite of specifications based on HL7's Reference Information Model (RIM). The Version 3 Normative Edition represents a new approach to clinical information exchange based on a model driven methodology that produces messages and electronic documents expressed in XML syntax.
ISO (International Organization for Standardization)	A worldwide federation of national standards bodies from more than 160 countries, with one standards body representing each member country.
ISO DCM (ISO/TS Detailed Clinical Models)	Detailed clinical models, characteristics and processes, is a standard that describes principles, requirements, governance, methods and a Logical Model to define Detailed Clinical Models.
Isosemantic Model	A model that, while different in structure, represents the same semantic content as another model. Any particular detailed clinical model exists within a family of isosemantic siblings.
Logical Model	A data model expressed in terms of data structures such as relational tables and columns, object-oriented classes, or XML tags. A logical model is expressed independently of a particular database management product or storage technology (physical data model).
Measure	
MOF (Meta Object Facility)	
MDA (Model Driven Architecture)	An approach to software design, development and implementation spearheaded by the OMG. MDA provides guidelines for structuring software specifications that are expressed as models.
Normal Form	A defined standard structure for relational databases in which a relation may not be nested within another relation.
OMG (Object Management Group)	The Object Management Group® is an international, open membership, not-for-profit technology standards consortium.
openEHR	openEHR is an open standard specification in health informatics that describes the management and storage, retrieval and exchange of health data in electronic health records.
PIM (Platform Independent Model)	___ TBD ____
Platform Specific Model	___ TBD ____
Polymorphic model	A model representing relationships from one class to multiple classes (e.g., observations, procedures, encounters, public health reports, supply, medications, exposure)
Post-coordinated concept	A notion represented by language, which identifies one idea. These are terms which are considered single concepts within the host terminology.
Pre-coordinated concept	A notion represented by language, which identifies one idea. These are terms which are considered single concepts within the host terminology.

Prerequisite	A prerequisite is a state that must exist prior to the performance of an action. It is clinical information that will be modeled as an independent clinical statement which will then be associated with other clinical statements that require this clinical information as a prerequisite.
Procedural Knowledge	
Reproducible	Multiple users or systems apply the ANF to the same situations and source data with the same/similar result.
Separation of Concerns	A design principle that allows a complete system to be subdivided into distinct sections or components with well-defined functionality and dependencies. If successful, this approach allows individual sections to be able to be reused, as well as worked on and updated independently to address new requirements and use cases.
Situation with Explicit Context	A SNOMED Concept Model that defines the context of a clinical finding or procedure.
ECL (SNOMED CT Expression Constrain Language)	The SNOMED CT Expression Constraint Language is a formal language for defining bounded sets of clinical meanings represented by either precoordinated or postcoordinated expressions.
Solor	A project sponsored by the Department of Veterans Affairs that represents and brings together different terminology standards by using a single model that can encompass any customized content. Solor allows informaticists and developers to convert user-supplied terminologies into a single model using open source software to produce Solor content. For more information please see http://solor.io
Statement	A representation of a fact or situation was observed to exist or happen. See Also Clinical Statement, Statement Narrative.
Statement Model	
Statement Narrative	A written account of a fact or situation was observed to exist or happen, corresponding to one or more statements. See Also Clinical Statement, Statement.
Input Forms (Structured Clinical Input Forms)	The manner by which clinicians author clinical statements and enter them into their organizations' electronic health record (EHR). Input forms have an impact as to how information is presented to the clinicians and how they enter the data, such as by constraining the information to allow only certain values to be entered, such as through a drop-down list or radio button, or breaking up large chunks of related information into smaller parts.
SME (Subject Matter Expert)	
Systematized Nomenclature of Medicine	Clinical Terms is a standardized, multilingual vocabulary of clinical terminology that is used by physicians and other health care providers for the electronic exchange of clinical health information.
Technique	A technique is a method applied, device used, or a temporary state in which the patient was actively placed at the moment in time of the performance of an action. It is clinical information that will be modeled as part of the topic of a clinical statement.
Terminology Knowledge	The Terminology Knowledge layer is responsible for structured sets of medical terms and codes that define concepts of interest, including descriptions, dialects,

	language, and semantic hierarchy. SNOMED CT, LOINC, and RxNorm are part of this layer.
Topic expression	The ‘topic’ is the clinical entity described by a clinical statement.
Understandable	The content of an ANF statement can be processed by health IT systems and understood by most healthcare providers, without reference to private or inaccessible information.
URU (Understandable, Reproducible, Useful)	A design principle that defines the solution to be Understandable, Reproducible, and Useful. See Also Understandable, Reproducible, Useful
UML (Unified Modeling Language)	Unified Modeling Language is an Object Management Group (OMG) specification defining a graphical language for visualizing, specifying, constructing, and documenting the artifacts of distributed object systems. [defintion from OMG]
Useful	The ANF statement has a practical value: analysis, research, outcomes, etc. that requires information aggregated across health IT systems.

9. Bibliography

Bibliography

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Appendices

A. Current CIMI Clinical Statement Modeling Effort

This chapter describes the CIMI clinical statement model. This model uses a traditional structured data tree approach which can then be compared and contrasted with the ANF model.

The central focus of the CIMI Reference Model is the CIMI Clinical Statement. A CIMI Clinical Statement represents structured electronic communication made about a patient typically documented as an 'entry' in the patient record. For example, a CIMI Clinical Statement can be used to represent the following statements made about a patient.

- Patient has diagnosis of congestive heart failure.
- Patient has a family history of breast cancer.
- Patient has a goal of smoking cessation.
- Patient has an order for Physical Therapy.
- Patient has a lab result of Serum Sodium equals 130 mEq/L with delta flag.
- Patient had an appendectomy.

CIMI Clinical Statement, shown in Figure A.1, has a ‘topic’, ‘context’, and ‘various metadata’. The ‘topic’ is the clinical entity being described. The ‘context’ describes the circumstances that form the setting in which the ‘topic’ should be evaluated. Finally, ‘various metadata’ is shown in the diagram for purely illustrative purposes to represent the collection of attributes that represent the who, where, why and when information. But 'various metadata' itself is not actually an attribute of CIMI Clinical Statement.

CIMI adopts a compositional approach rather than inheritance, where a particular topic and context are added to a CIMI Clinical Statement. But topics and contexts themselves are defined with inheritance. This is the same general approach taken by ANF except for the following differences. CIMI defines the topic as a structured tree where ANF defines topic as a post-coordinated SNOMED CT expression. Both CIMI and ANF define context as a structured tree, but ANF has alternatively named 'context' to be 'circumstance'.

Figure A.1. Clinical Statement

Topic The ‘topic’ is the clinical entity described by the Clinical Statement. A few examples of topic include clinical assertions, evaluation results, and procedures. For each of these topics the information described is quite different. Therefore, CIMI describes topic types that contain the appropriate attributes to describe the required information for the given topic. The number of topic types will change as CIMI progresses. Currently the allowable topic types are ProcedureTopic and FindingTopic which has subtypes of EvaluationResultTopic and AssertionTopic.

- ProcedureTopic
- FindingTopic
  - EvaluationResultTopic
  - AssertionTopic

In ANF, these various structured trees representing the topic will all be represented with SNOMED CT post-coordinated expressions. Some CIMI uses of topic will be illegal in ANF. For example, if CIMI modeled using EvaluationResultTopic with a coded result in the Context, this would not be possible in ANF because ANF does not allow coded results. Instead, this would need to be modeled in an AssertionTopic style with the result moved into the topic to be representable by ANF.

Context The ‘context’ describes the circumstances that form the setting in which the ‘topic’ should be evaluated. The various CIMI context types contain the appropriate attributes required for the given context. The number of context types will change as CIMI progresses. Currently the allowable context types are ActionContext and FindingContext. ActionContext has subtypes with examples including RequestContext, OrderContext and PerformanceContext. FindingContext has subtypes with examples such as PresenceContext, AbsenceContext, and GoalContext.

- ActionContext
  - RequestContext
  - OrderContext
  - PerformanceContext
- FindingContext
  - PresenceContext
  - AbsenceContext
  - GoalContext

ANF has alternatively named 'context' to be 'circumstance' but it serves the same function in both models. A major difference is that ANF only allows quantitative results whereas CIMI also allows coded results. Another difference is that ANF describes all quantitative results as a range. This allows ANF to describe presence and absence using this quantitative range, thus eliminating the need for many of the CIMI contexts describing presence and absence

Metadata ‘metadata’ is not actually an attribute of CIMI Clinical Statement, but is intended to represent the various attributes in a clinical statement that represent metadata about the clinical statement. This includes attribution information relating to the statement itself such as who authored, verified, recorded, or signed the statement or more informally, the who, where, why, and when information. Other attributes of this nature are recordStatus and encounter.

A.1. Examples Using Topic and Context

Earlier, descriptive examples of textual examples of clinical statements were given. Here we will represent a few of these examples using the CIMI Clinical Statement ‘topic - context’ paradigm. In Whatever. Fix ME!, the example for “Patient has diagnosis of congestive heart failure” is illustrated. The topic has been declared to be of type AssertionTopic stating “assertion of congestive heart failure”, and the context has been declared to be of type PresenceAbsenceContext stating “Known Present”. What may not be apparent in the figure is that when the topic is declared to be of type AssertionTopic then all the attributes of AssertionTopic are available for use. However, in the figure only the attribute named 'topicCode' is shown for clarity.

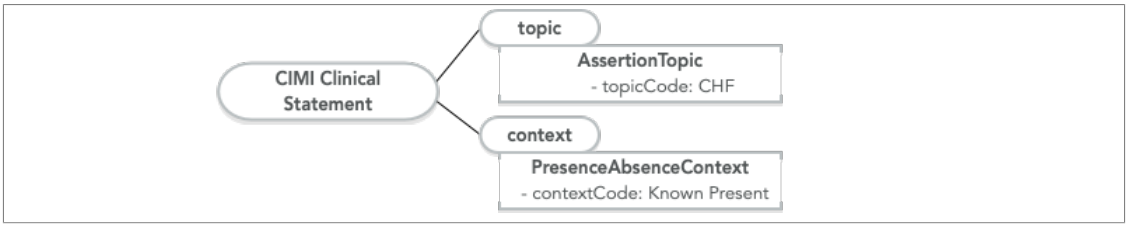

Figure A.2. Patient has diagnosis of congestive heart failure.

In Whatever, Fix me!, the example for "Patient has an order for Physical Therapy." is shown. The topic has been declared to be of type ProcedureTopic stating "procedure of type physical therapy", and the context has been declared to be of type OrderContext. Again, the majority of attributes for ProcedureTopic and OrderContext are not shown for clarity.

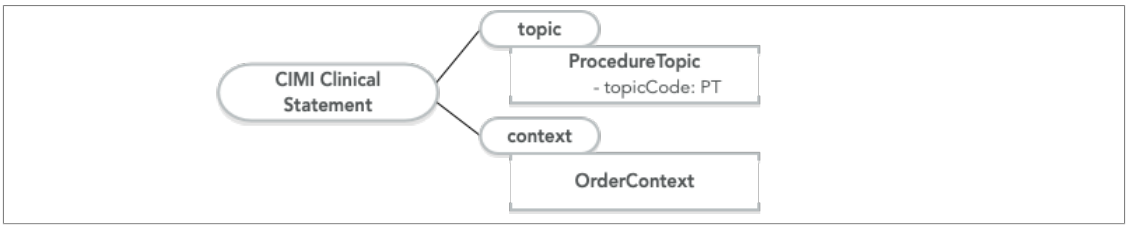

Figure A.3. Patient has an order for Physical Therapy.

StatementTopic and StatementContext are both collections of attributes and have the following characteristics:

1. They are reusable components that can be assembled to form clinical statements. For instance, one can coordinate the ProcedureTopic with the ProposalContext to represent a ProcedureProposal statement. Alternatively, ProcedureTopic may be paired with OrderContext to create a ProcedureOrder statement.

2. They represent groupings of attributes aligned with the SNOMED CT Concept Model. For instance, ProcedureTopic is aligned with the SNOMED CT Procedure Concept Model. PerformanceContext aligns with the Situation with Explicit Context (SWEC) Concept Model.

3. They provide for a mechanism to state presence or absence of a finding as well as performance or non-performance of an action. For instance, the pairing of ProcedureTopic with NonPerformanceContext allows for the expression of a procedure that was not performed.

A.2. CIMI Topic Patterns

Topic Patterns include all the attributes required to fully describe a clinical entity. The topic patterns CIMI has developed to date include FindingTopic and ProcedureTopic, with FindingTopic having children of AssertionTopic and EvaluationResultTopic. They are shown in Figure A.4 and are described in the following sections. Each of these topic subtypes contain a collection of attributes that describe the given pattern. These patterns provide the foundational structure for detailed clinical model (DCM) archetype instances that can be visualized at http://models.opencimi.org

ANF, on the other hand, does not create its own topic patterns, and instead relies on SNOMED CT post-coordinated expressions to represent the topic. ANF operates under the principle of separation of concerns, and believes that terminology should be a separate concern from the ANF Statement data structure and its properties.

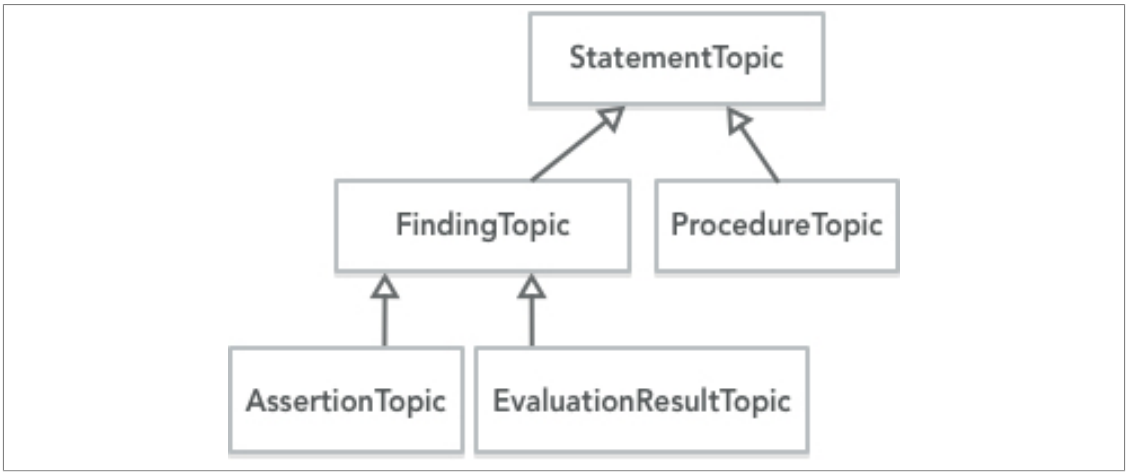

Figure A.4. Topic Hierarchy

A.2.1. AssertionTopic

The first CIMI topic type described here is the AssertionTopic pattern with its included attributes, as shown in Figure A.5. Not shown in the previous diagram is that AssertionTopic has been further refined with subtypes. ConditionTopic, shown in Figure A.6 is a child of AssertionTopic which is used to represent clinical findings such as the presence (or absence) of a condition in a patient. For example:

- Assert the presence of chest pain.
- Assert the absence of chest pain.
- Assert the presence of edema.

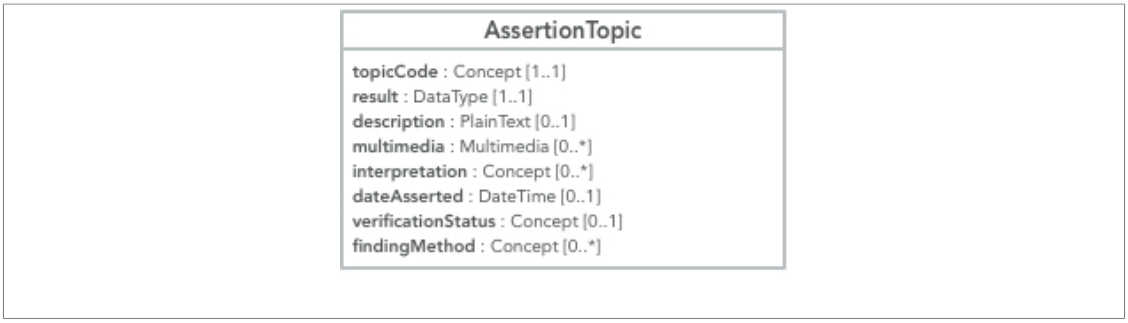

Figure A.5. AssertionTopic

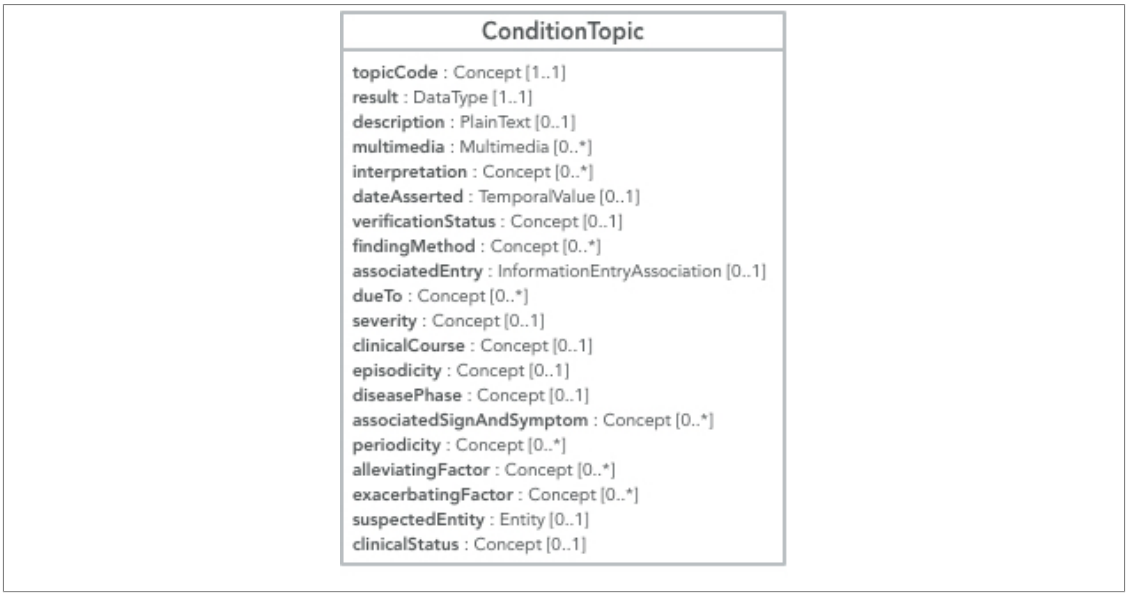

Figure A.6. ConditionTopic

The assertion pattern for a clinical statement is as follows:

- topic.topicCode = a code representing what is being asserted (e.g., “rash”, “auto accident”, “hypertrophy”, etc.).
- context.contextCode = a code representing presence or absence.

A.2.1.1. Assertion Hierarchy

The full hierarchy for AssertionTopic is shown in Figure A.7. AssertionTopic serves the following purposes: (1) it provides the core set of assertion attributes that are relevant in assertion of presence and absence; and (2) it is the parent type for the more specific assertions such as ConditionTopic and FindingSiteAssertionTopic. If additional attributes are identified as required to properly model assertions, they would either be added to one of the existing assertion types or a new type could be created with these attributes. This modeling decision would be based on whether adding these attributes make sense for existing assertions or only for a new subset of assertions. Typically an attribute is added to the parent class if that attribute is relevant in all the subclasses derived from the parent class. If an attribute is only relevant in some of the subclasses, then the attribute is introduced in these subclasses. This ensures that a class does not have an attribute that is incongruent and thus requires that attribute to be frequently constrained out. As an analogy, CIMI wants to minimize the design practice that would create an Animal class that contains arms, legs, and wings and then create an instance of a dog that constrains out wings since dogs do not have wings.

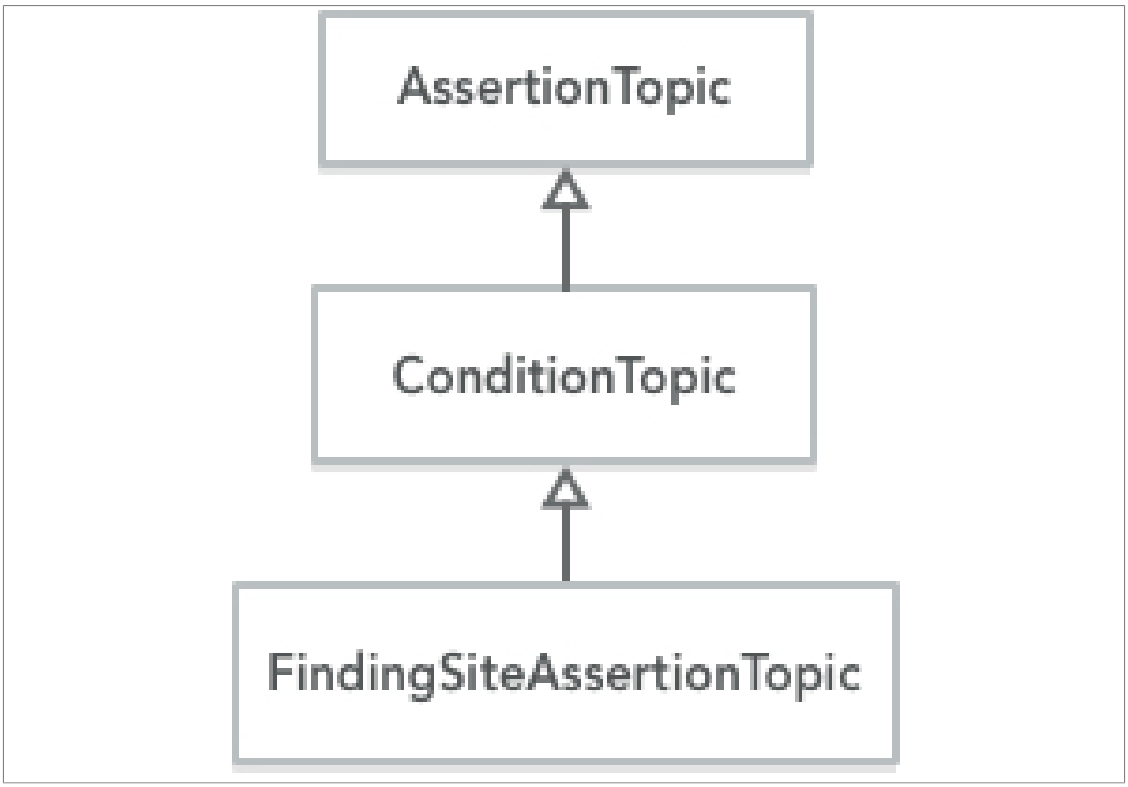

Figure A.7. Assertion Hierarchy

A.2.1.2. Assertions

Assertions affirm or deny the existence of clinical conditions, diseases, symptoms, etc., in the patient. As just described, different varieties of assertion may extend an existing AssertionTopic class with any additional attributes necessary to fully represent this new group of assertions. In the following sections, Whatever, fix me! and Example A.2 show examples of clinical statements using the AssertionTopic class for the topic, and later, Example A.3 and Example A.4 show examples of clinical statement using FindingSiteAssertionTopic for the topic. These examples show the 'topic.topicCode' and 'context.contextCode' for each, with the addition of any extra attributes from the chosen topic needed to describe the clinical statement. Context will be discussed in depth later in this document. For now, be aware the chosen context is a full class with many attributes but here we are only showing the context code attribute that is common to all context types.

Example A.1. The patient has diabetes mellitus type 1 which was diagnosed at age 24

```
Diabetes Mellitus (Assertion Instance)
    topic.topicCode: Diabetes mellitus type 1 (disorder)
    topic.ageAtOnset: 24 years
    context.contextCode: Confirmed present (qualifier value)
```

Example A.2. The patient does not have diabetes mellitus type 1

```
Diabetes Mellitus Absent (Assertion Instance)
    topic.topicCode: Diabetes mellitus type 1 (disorder)
```

```
context.contextCode: Known absent (qualifier value)
```

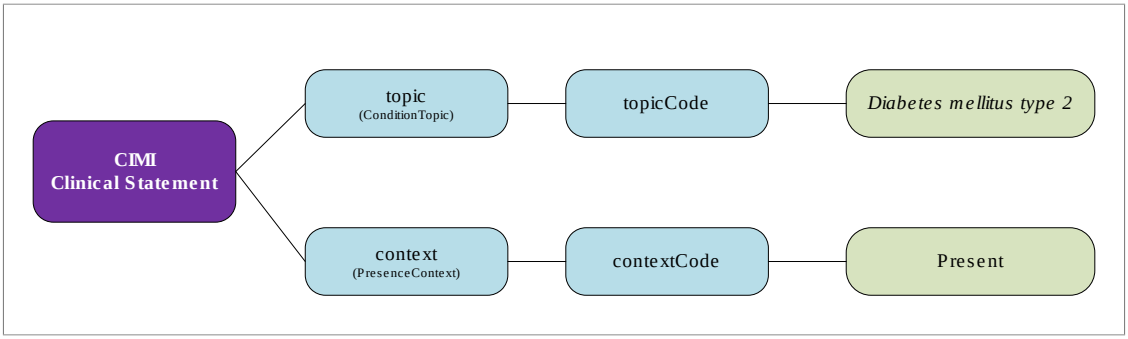

Figure A.8. CIMI Diabetes Mellitus Type 2 Assertion

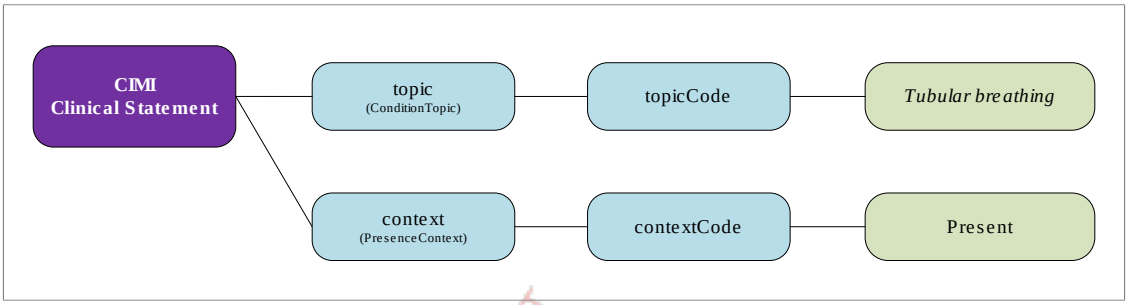

Figure A.9. CIMI Tubular Breath Sounds Assertion

Note, in the CIMI alignment with the SNOMED CT concept model, the AssertionTopic pattern corresponds to the Finding hierarchy as inflected by the Situation hierarchy.

Other attributes may also inflect the semantics; e.g., an AssertionStatement.topic.findingMethod that would align with the concept model's Finding.findingMethod.

A.2.1.3. Finding Site Assertions

A FindingSiteAssertionTopic is an assertion about a finding found on the body. This assertion is a "design by extension" assertion because it contains the additional attribute findingSite that is used to capture the body site affected by the condition. The FindingSiteAssertionTopic encourages post-coordination as shown in Example A.3 and Example A.4, and intentionally aligns with the SNOMED CT Clinical Findings concept model.

Example A.3. The patient has a femur fracture in the right leg

```
FractureAssert (Finding Site Assertion Instance)
    topic.topicCode: Fracture of bone (disorder)
    topic.findingSite.code: Bone structure of femur
    topic.findingSite.laterality: Right (qualifier value)
    context.contextCode: Confirmed present (qualifier value)
```

Example A.4. The patient has a stage two pressure injury on the right ischial tuberosity

```
WoundAssert (Finding Site Assertion Instance)
    topic.topicCode: Pressure ulcer stage 2 (disorder)
    topic.findingSite.code: Skin structure of ischial tuberosity
    topic.findingSite.laterality: Right (qualifier value)
    context.contextCode: Confirmed present (qualifier value)
```

A.2.2. Evaluation Result

The second topic pattern we will discuss is EvaluationResultTopic which is used to document a characteristic of a patient or a clinical value being observed. An EvaluationResultTopic may hold the name of a test in the 'topicCode' attribute (e.g., "heart rate evaluation", "serum glucose lab test", etc.) and the resulting value of the test would be represented in the context 'result' attribute. Viewed another way, the EvaluationResultTopic topicCode holds a question (e.g., "what is the heart rate?", "what is the serum glucose?") and the context 'result' holds the answer. Any clinical statement such as a laboratory test, a vital sign, or a questionnaire question that fits this pattern of a question and a resulting value is modeled with the EvaluationResultTopic pattern.

The evaluation result pattern for a clinical statement is as follows:

- topic.topicCode = what's being evaluated ("heart rate", "serum glucose", "breath sound", etc.).
- context.result = the result of the evaluation ("72 bpm", "100 mg/dL", "rales")

The following is an isosemantic comparison of the evaluation result pattern to the previously described assertion pattern using blue eye color as an example

Assertion	• topic.topicCode = blue eye color • context.contextCode = present
EvaluationResult	• topic.topicCode = eye color • topic.result = blue eye color

Like Assertion, Evaluation Result corresponds to the SNOMED CT concept model. The EvaluationResultStatement.topic.topicCode attribute corresponds to the observation being evaluated.

A.2.2.1. Evaluation Result Hierarchy

EvaluationResultTopic currently has two subtypes; LaboratoryTestResultTopic (which includes additional attributes necessary to describe laboratory tests) and PhysicalEvaluationResultTopic.

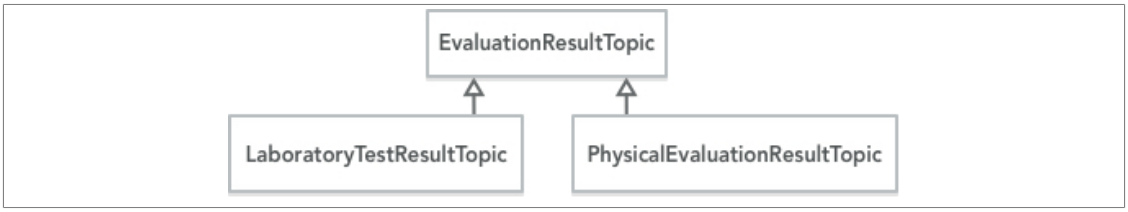

Figure A.10. Evaluation Result Hierarchy

A.2.2.2. Modeling in the Constraint Layer

This section will use LaboratoryTestResultTopic, which exists in the Reference Model Layer, to further describe modeling in the Constraint Layer. There are different categories of laboratory tests that differ

in their resulting data type, such as quantitative labs and nominal labs, where the former would have a Quantitative result and the latter would have a Coded result. For the different lab categories there is not a need for new named attributes to be added in the reference model layer, but only a need to constrain the result to the appropriate datatype. Since a new named attribute is not required, the style CIMI has adopted is to create subtypes in the constraint layer, where in this case, an ADL Archetype would be created for both QuantitativeLaboratoryTestResult and NominalLaboratoryTestResult.

A.2.2.3. Evaluation Result Subtypes in the Reference Layer

LaboratoryTestResultTopic LaboratoryTestResultTopic contains attributes specific to the lab evaluation process. These include information about the physical process (e.g., specimen) plus process management information (e.g., status).

PhysicalEvaluationResultTopic PhysicalEvaluationResultTopic contains attributes specific to the clinical evaluation process. These include information about the physical examination process (e.g., patient position, body site).

Example A.5. The patient's skin turgor is friable

```
SkinTurgorEval (Physical Evaluation Result instance)
    topic.topicCode: Skin turgor (observable entity)
    topic.evaluationProcedure: Inspection (procedure)
    context.result: Fragile skin (finding)
```


Example A.6. The patient's systolic blood pressure is 120 mmHg

```
SystolicBloodPressureEval (Physical Evaluation Result instance)
    topic.topicCode: Systolic arterial pressure (observable entity)
    context.result: 120
        unitsOfMeasure: Millimeter of mercury (qualifier value)
```

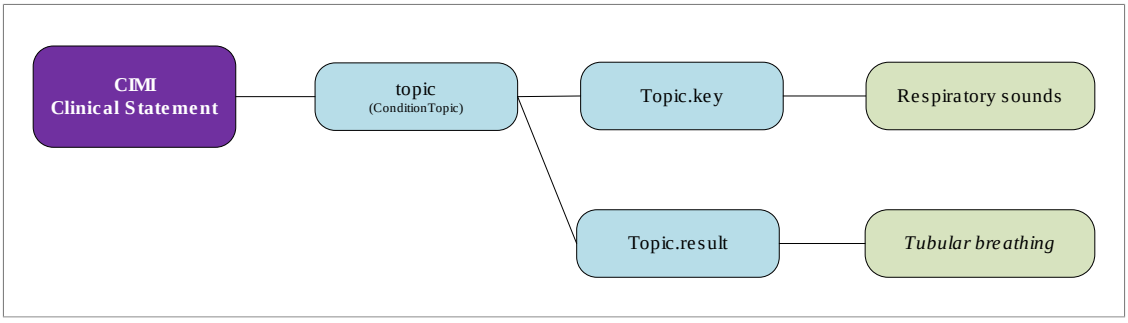

Figure A.11. CIMI Tubular Breath Sounds Evaluation

Figure A.12 and Figure A.13 are both Evaluation Result style representations of a systolic blood pressure. In the first, where CIMI has a simple topic, the style is very similar to how it would be modeled in ANF. But in Figure A.13, which has a complex topic, CIMI represents this with named properties in a tree structure. ANF, on the other hand, would put all this structured topic complexity into a post-coordinated SNOMED CT expression.

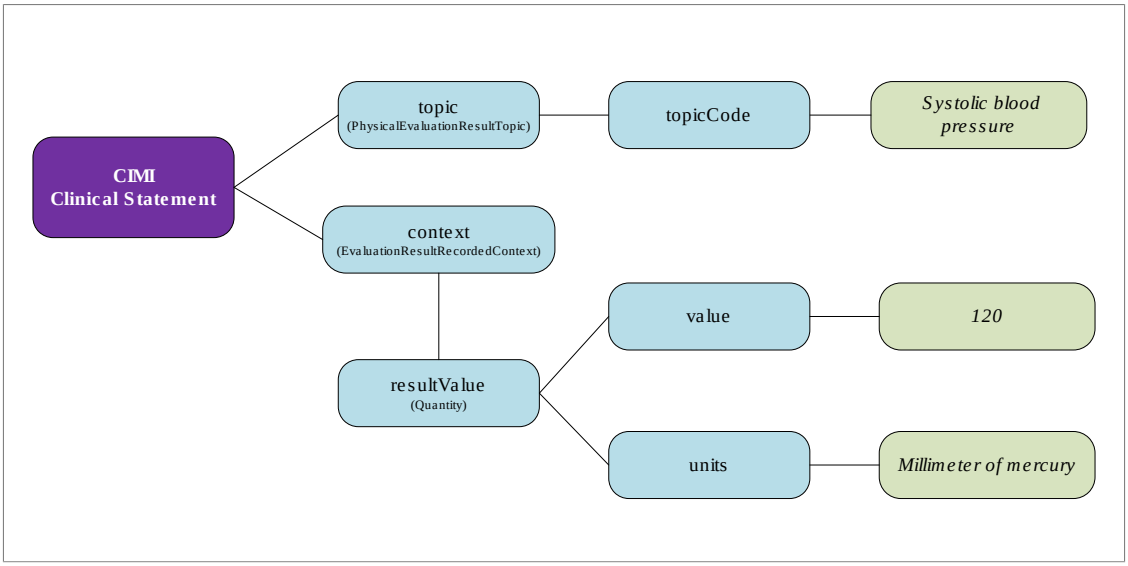

Figure A.12. CIMI Systolic Blood Pressure 120 mmHg Evaluation

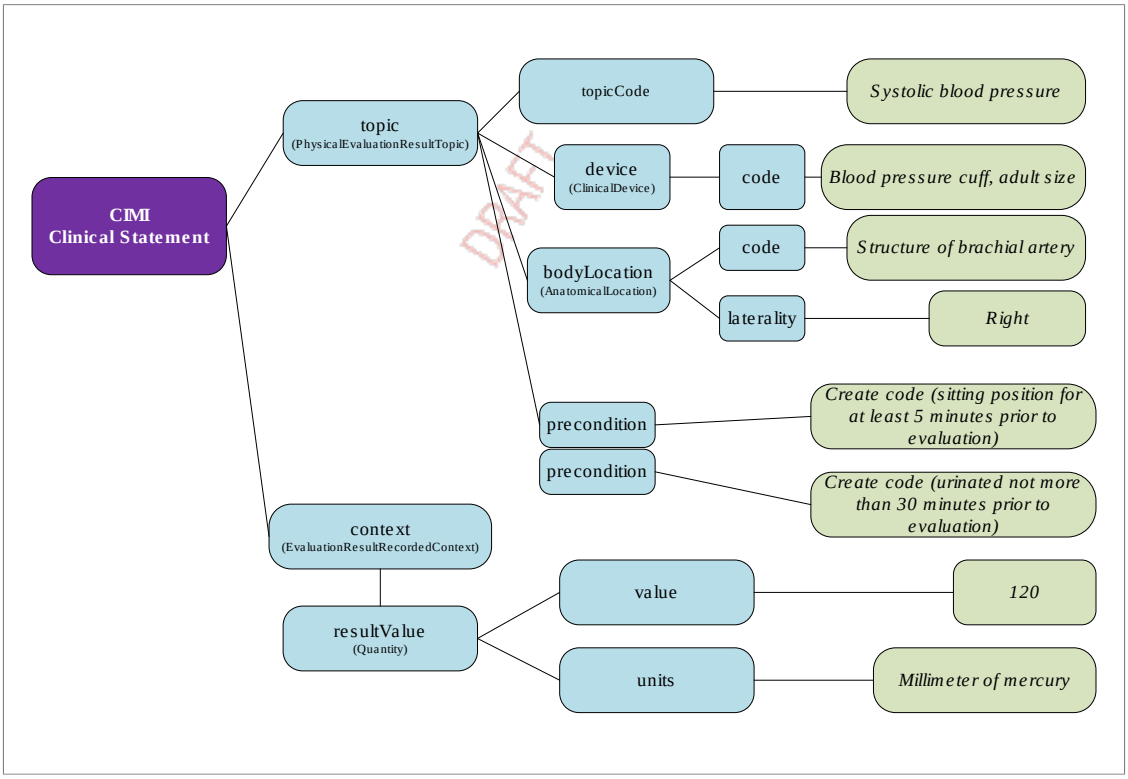

Figure A.13. CIMI Systolic Blood Pressure 120 mmHg, Taken on Right Brachial Artery, Using BP Cuff Adult Size, Patient in Sitting Position for at Least 5 Minutes, Urinated Not More than 30 Minutes Prior to Measurement Evaluation

A.2.2.4. Guideline: Assertion versus Evaluation

Any evaluation model may be transformed into an assertion model. Conversely, any assertion model may be transformed into an evaluation model. Some more easily than others.

The general guideline is if it is natural to think of the concept as a noun, as a condition or state that exists in the patient, model as an assertion or set of assertions. If the statement about the patient is thought of as a name/value pair (i.e., a noun representing the attribute and an adjective representing the value), such as “hair color” = (“black”, “brown”, “blonde”), then model it as an evaluation. However, it is important to note both styles are allowed and the true determinant of their use is whether a result for a given criteria other than true/false or present/absent is specified.

This discussion highlights the importance of isosemantic models. Even if one model or set of models can be agreed upon as the preferred style (e.g., assertion models for “bradycardia” and “tachycardia” instead of an evaluation model with “bradycardic” and “tachycardic” as values), inevitably there will be use cases (e.g., data entry, messaging, reporting, etc.) for the other model and a need to identify use cases where different modeling patterns describe semantically identical phenomena. These patterns are isosemantic. An essential (as of now unfulfilled) requirement is for a mechanism of identifying isosemantic models, managing isosemantic groups, and transforming between them. We expect a great deal of this work to be facilitated by the semantic underpinnings of the models supporting the ability to classify the content of two models and determine their logical relations (equivalent, subsumed, disjoint).

It should be noted the Assertion vs. EvaluationResult topic is solely concerned with the structure and schema pattern used to capture clinical information. Choosing Assertion vs. EvaluationResult patterns has nothing to do with whether the information being captured is subjective vs. objective.

A.2.3. ProcedureTopic

Procedure models are used to represent actions taken related to the care of a patient such as a cholecystectomy, peripheral IV placement, delivery of a warm blanket, dressing change, ambulation, patient education, etc. The CIMI ProcedureTopic, as shown in Figure A.14, is a base class for a number of specializations such as surgical, imaging, and laboratory procedures. The CIMI Procedure Model is aligned with the SNOMED CT Procedure Concept Model when such an alignment exists.

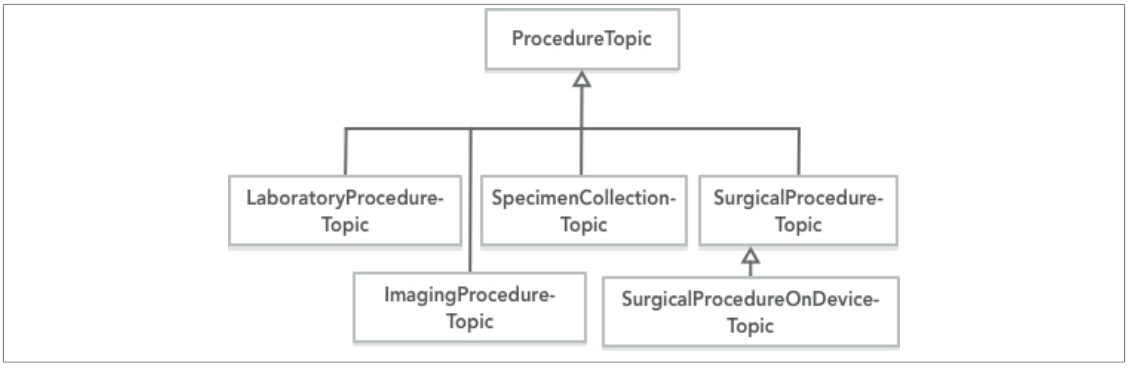

Figure A.14. ProcedureTopic Hierarchy

A.2.4. Context Patterns

When a Clinical Statement is defined it will be modeled as a combination of a topic and a context. The ‘context’ describes the circumstances that form the setting in which the ‘topic’ should be evaluated. Specializations within the context hierarchy, shown in Figure A.15, add important attribution information for the situation being described. This is a partial view of the context hierarchy for illustration purpose, but it should be clear that more context classes exist, and more will be modeled in the future as necessary.

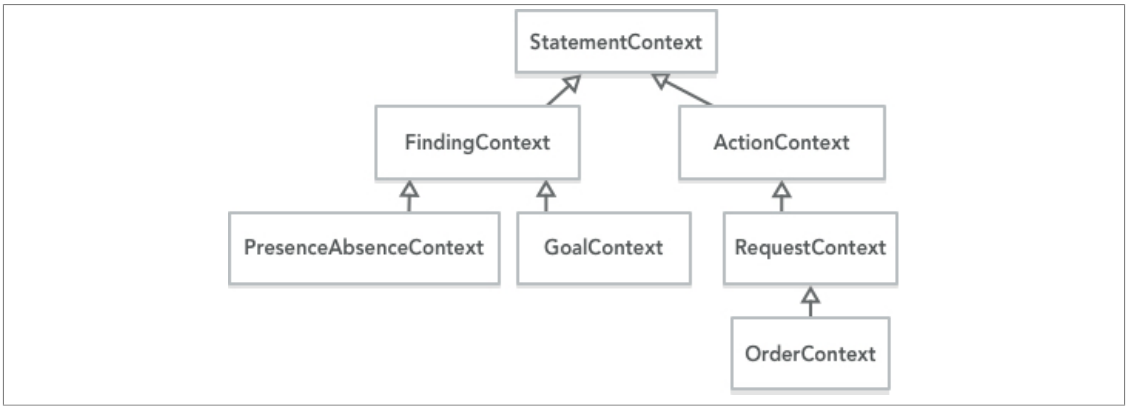

Figure A.15. Context Hierarchy

The StatementContext abstract class has the following specializations:

FindingContext The FindingContext class aligns with the SNOMED CT Situation with Explicit Context for findings and provides the context for either the EvaluationResultTopic or AssertionTopic of a clinical statement. For example, a context about a finding may state that the finding was present or absent.

ActionContext The ActionContext class aligns with the SNOMED CT Situation with Explicit Context for procedures and provides the context for the topic of a clinical statement. For instance, a statement about a procedure may specify the procedure has been proposed, ordered, planned, performed, or not performed. Each action context, in turn, has its own lifecycle. Another child of ActionContext, not shown in Figure A.15 is PerformanceContext shown in Figure A.16.

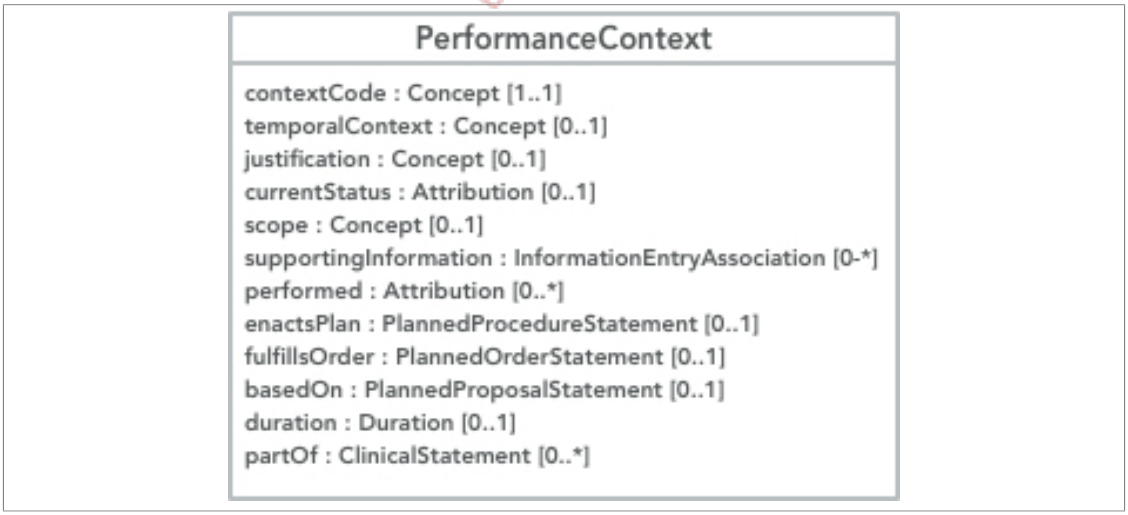

Figure A.16. PerformanceContext

B. Differences between ANF and CIMI

There are two fundamental differences between the ANF and CIMI Statement approach.

1. The representation of topic.
2. The representation of results.

B.1. The Representation of Topic

In the ANF Statement model, the topic is represented by a single field containing a simple to complex post-coordinated SNOMED expression, whereas in the CIMI Statement model, all the pieces of information that make up the topic can be broken out and structured as needed into a complex tree of objects with multiple properties and appropriate datatypes.

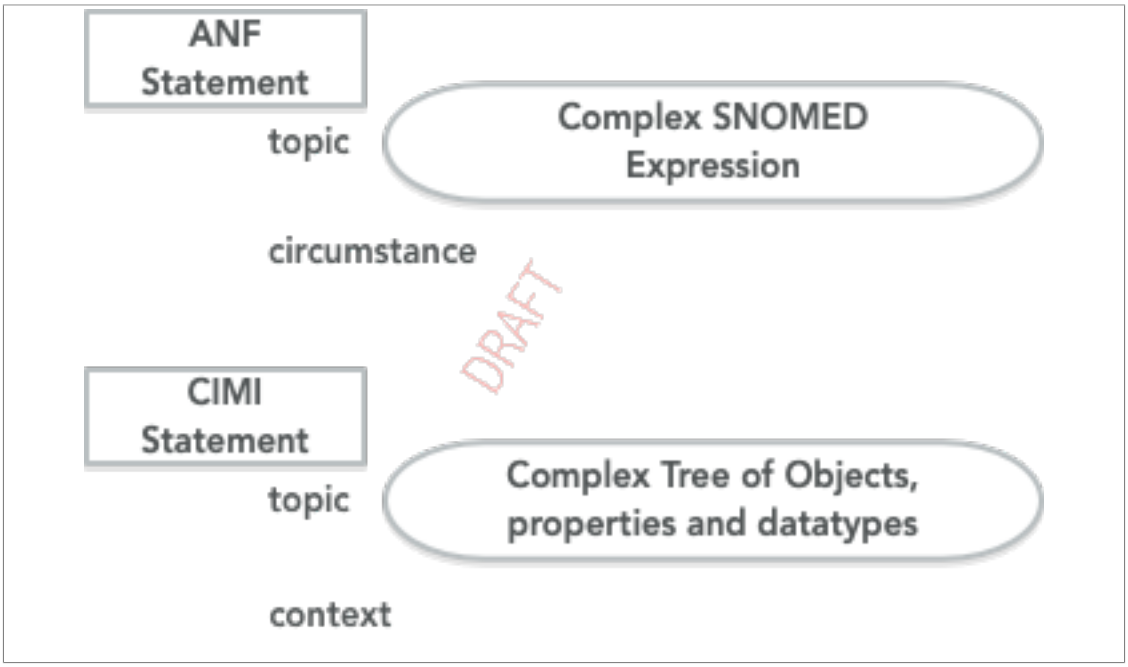

Figure B.1. Topic Comparison for a Complex Topic

As we can see in the Pulse Rate examples below, the ANF topic is represented as a post-coordinated expression while the CIMI topic is represented with a topic containing a single concept along with associated structural properties representing the pulse oximeter device. Since the ANF Statement will always be either the request for an action or the performance of an action, the post-coordinated expression will always be a procedure that is further refined providing a consistent representation.

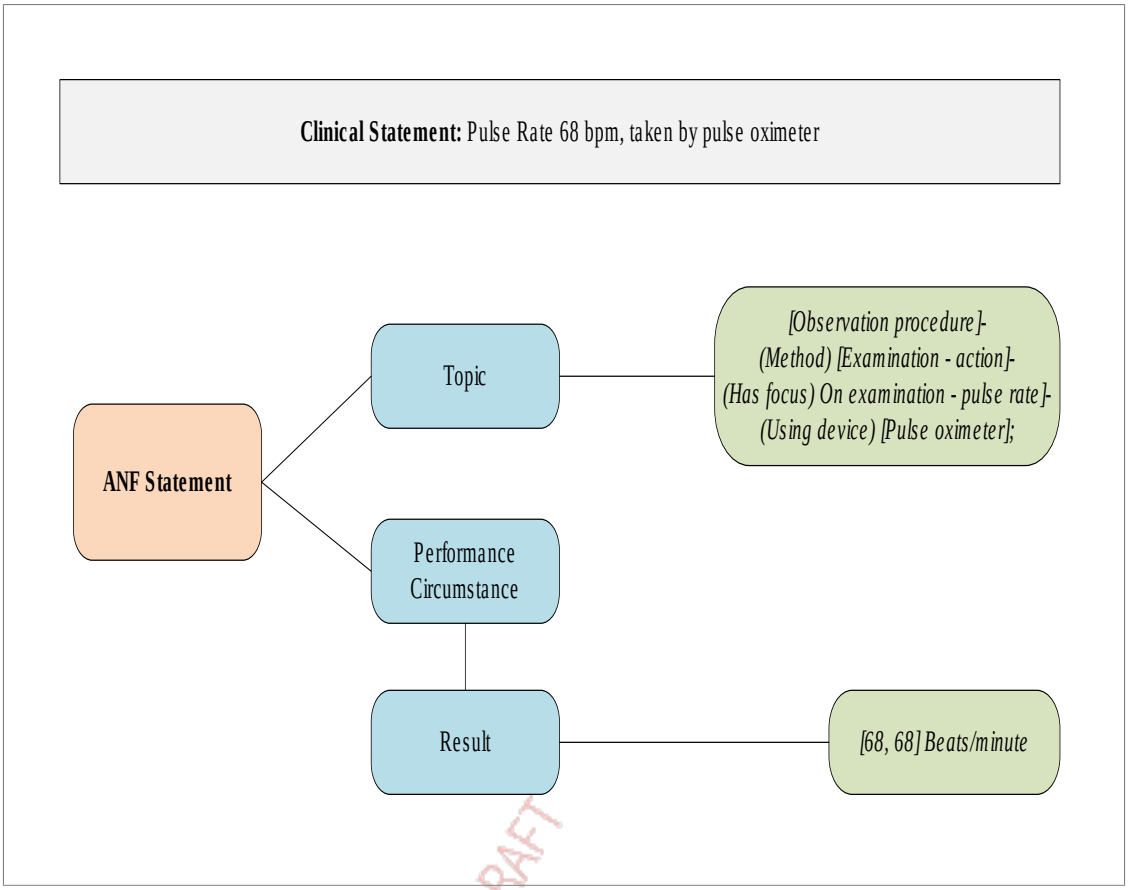

Figure B.2. Pulse Rate 68bpm, Taken by Pulse Oximeter - ANF Representation

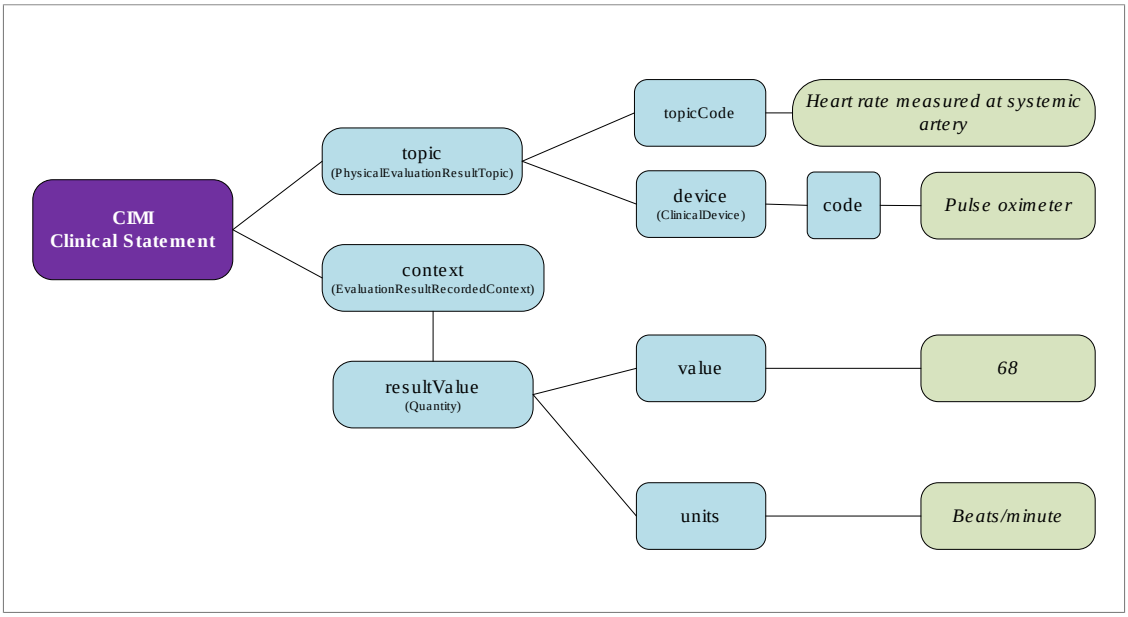

Figure B.3. Pulse Rate 68bpm, Taken by Pulse Oximeter - CIMI Representation

One implication of this is that the ANF is using two formalisms to represent the clinical statement. First it uses the formalism that represents the ANF reference model. Second, it uses SNOMED CT's syntax for

post-coordinated SNOMED CT expressions. Tools for authoring and analysis would be required to parse and process both syntaxes.

The CIMI Statement model in this example, on the other hand, would be fully represented using the formalism that represents the CIMI reference model. This model however allows for the possibility of multiple modeling style representations of the same data that are then not easily queried for equivalence.

B.2. The Representation of Results

In the CIMI model, EvaluationResult and Assertion models are used to represent observations. EvaluationResult has a topic representing what is being observed, and a result represented by a choice of datatypes. EvaluationResult can be thought of as a question and an answer. An Assertion on the other hand, has simply a topic stating what is observed, and a coded result stating presence or absence.

In the ANF model, the topic represents what is being observed and the result may only be a range of a quantity. No coded results are allowed. Not allowing coded results forces more of the semantics to be represented in the terminology model and limits the ability to allow multiple different representations of the same data. In the example below we see Dot blot hemorrhage represented in ANF as either present or with the number of hemorrhages that exist.

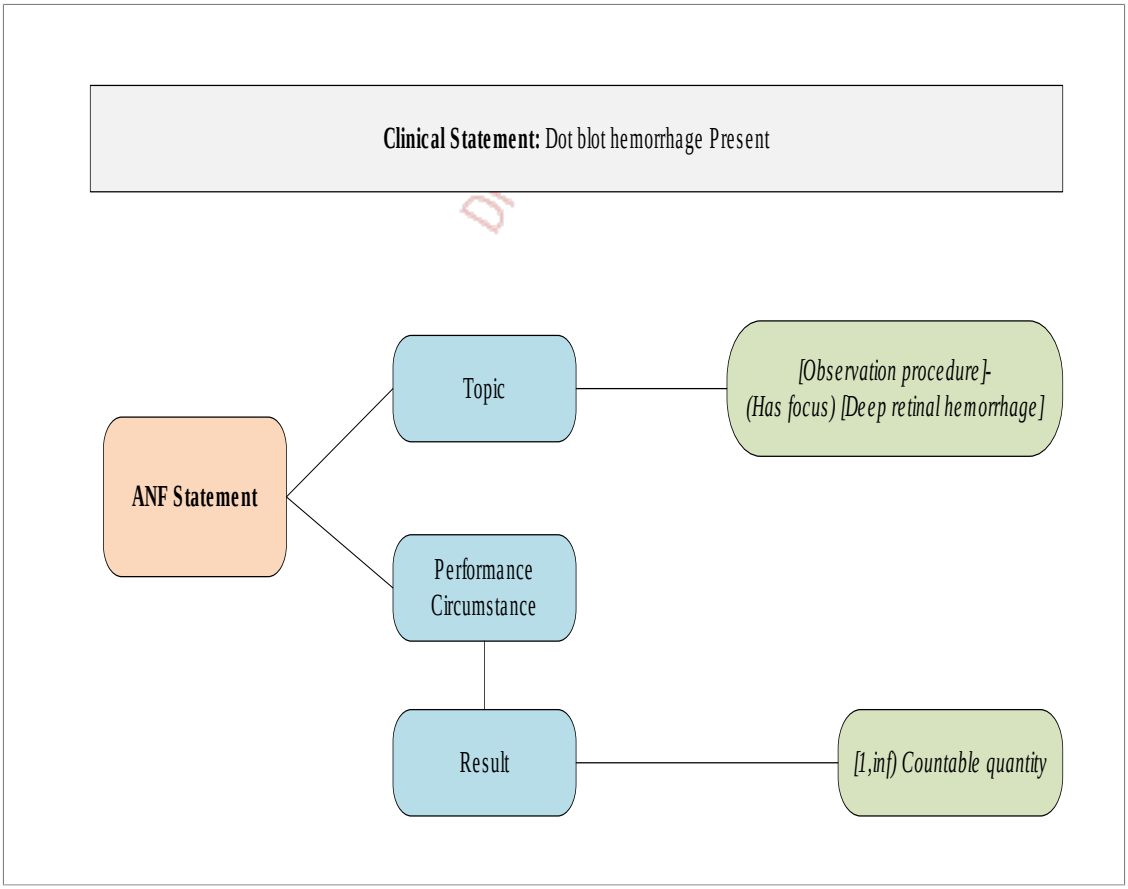

Figure B.4. Dot Blot Hemorrhage Present - ANF

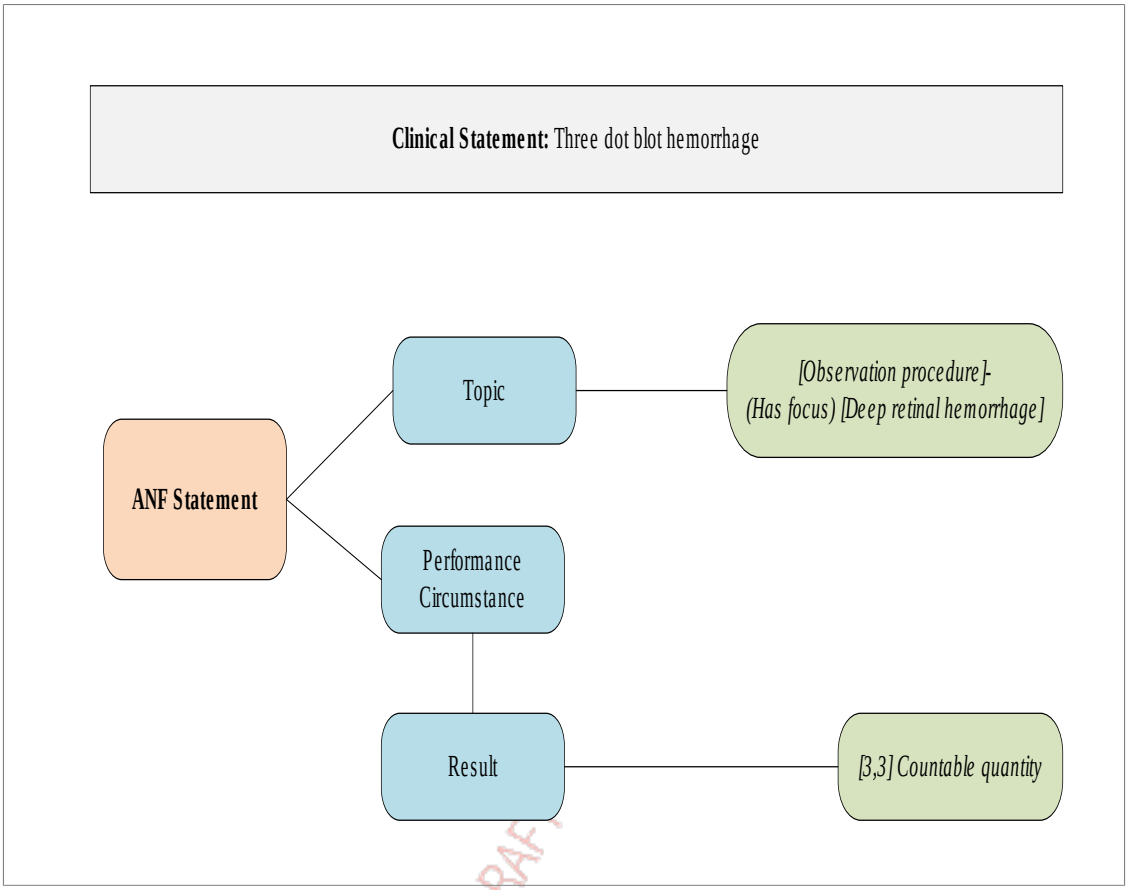

Figure B.5. Three Dot Blot Hemorrhage - ANF

In the CIMI Statement model, when creating a model with a numeric result, the choice is quite clear, and the choice will be an EvaluationResult, such as a topic of 'Systolic Blood Pressure' and result with a numeric quantity. In this case, the CIMI and ANF model are very aligned, except for the fact that the ANF model will always use a range of that quantity.

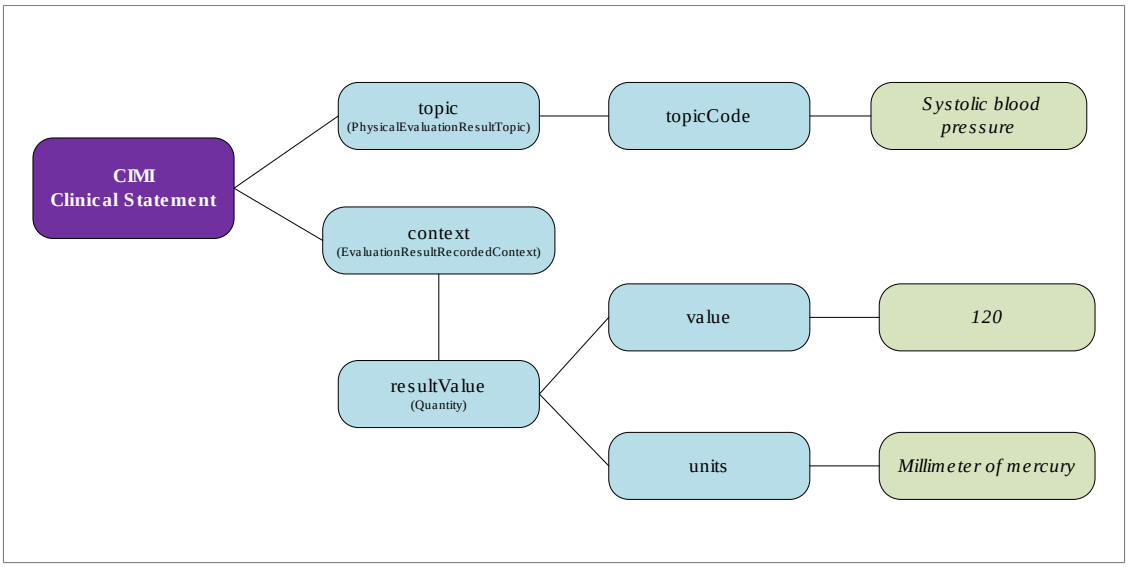

Figure B.6. Systolic Blood Pressure 120 mmHg - CIMI Representation

But when a CIMI model has a potential coded result, the choice between EvaluationResult and Assertion becomes muddied. For example, a model for Breath Sound could be an EvaluationResult with a topic of 'breath sound' and a coded result with the following valueset. Thus, any of the breath sounds within the valueset can act as a result for this model.

Breath Sound Value
Absent
Audible
Clear
Coarse Breath Sounds
Coarse Crackles
Crackles
Diminished
Expiratory wheezing
Faint
Fine Crackles
Forced
Inspiratory wheezing
Left Ventricular Assist Device Noise
Markedly Decreased
Moderately Decreased
Pleural Rub
Prolonged Expiration
Rhonchi
Slightly Decreased
Stridor
Tubular Breath Sounds
Upper Airway Congestion
Wheeze

Table B.1. Breath Sound Valueset

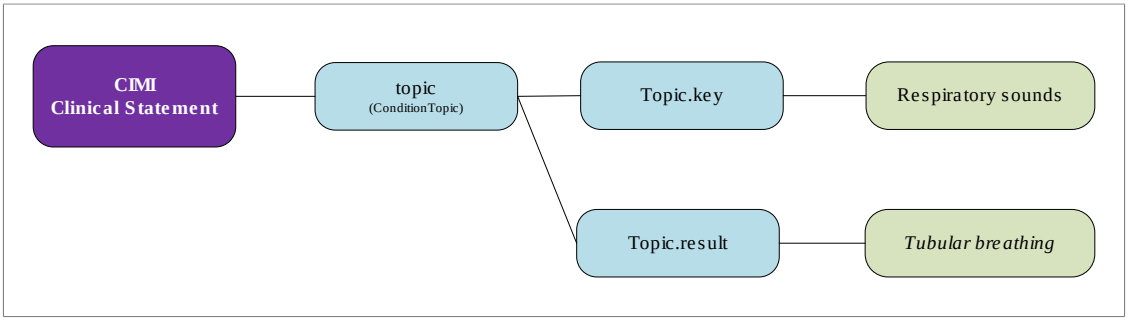

Figure B.7. Tubular Breath Sounds - CIMI Evaluation Representation

The other option, is that each of the breath sounds in the valueset is modeled as an Assertion with a topic of Tubular breathing and a contextCode indicating presence or absence. To decide which model is better,

usually we ponder how the clinician thinks about the data, or how it will be collected, or how it will be queried.

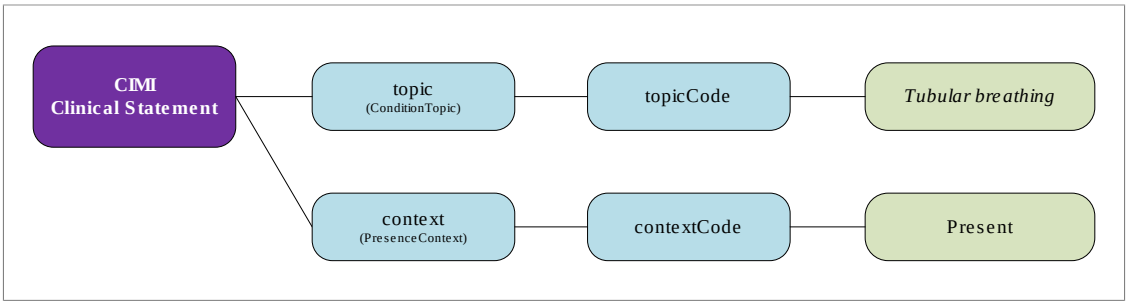

Figure B.8. Tubular Breath Sound - CIMI Assertion Representation

In this example, the ANF model doesn't support an EvaluationResult style model as it doesn't allow coded results. Thus, ANF is forced to make one and only one choice, which is an assertion style where the particular breath sound is the topic, and the result will be a countable quantity indicating presence or absence.

When querying instance data, the Assertion or ANF style can be more difficult to represent as it requires concepts to be pre-coordinated in the terminology or having sufficient semantics available in the concept model to allow for representation of a post-coordinated expression. To successfully query any breath sound instances using the Assertion/ANF style, the underlying terminology must be correctly modeled to support. If one of the breath sound values is not correctly placed under the higher level concept of 366135003 | Finding of breath sounds (finding)|, then retrieving all breath sounds will require knowledge of all the possible breath sound values. With the EvaluationResult style, querying is simpler as you simply query for a topic of 'breath sound', and the coded result tells you what type of breath sound it is. Thus, you do not have to know all the members of the valueset apriori to form the query.

B.3. ANF vs CIMI Examples

The following examples seek to highlight the differences between the ANF and CIMI models. These representations are at a graphic high level and are not intended to be exact representations.

B.3.1. Simple Systolic Blood Pressure Statement

In this systolic blood pressure example both the ANF and CIMI models are closely aligned. Since the ANF model requires both an upper and lower bound there is extra information required.

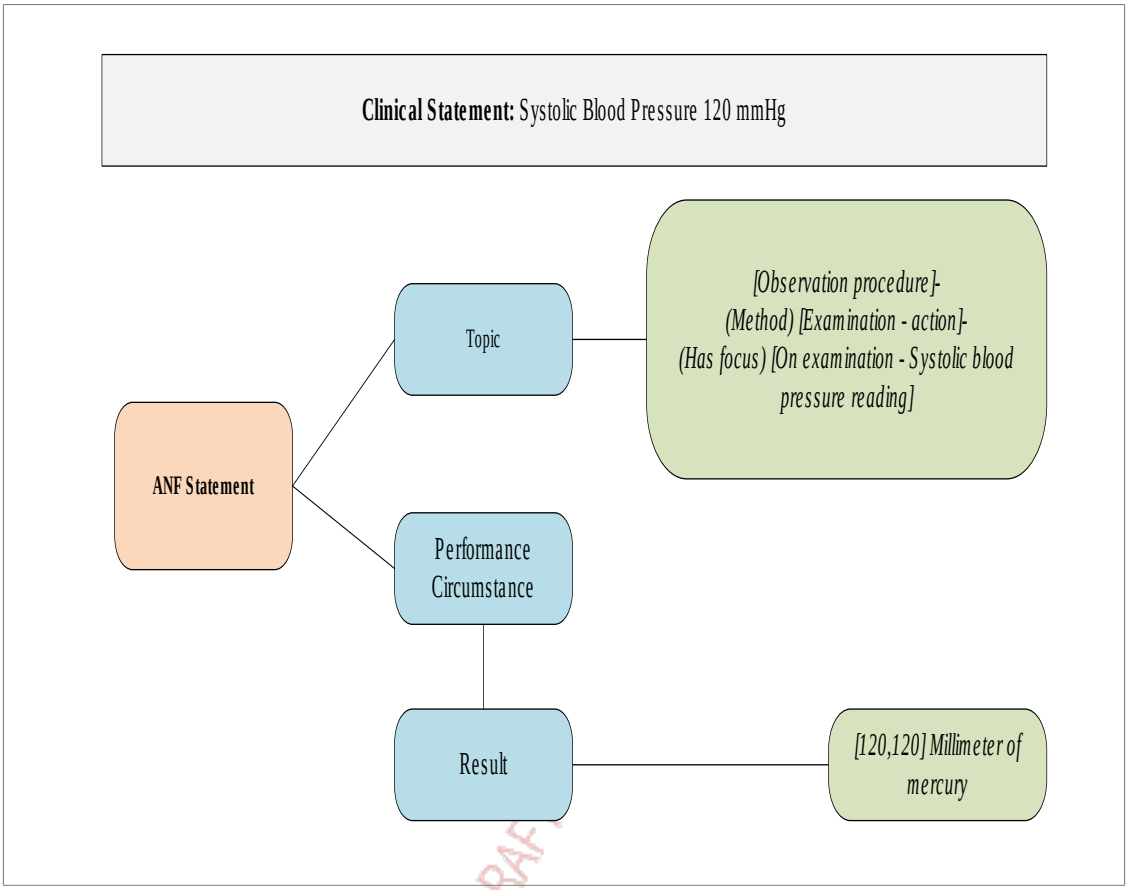

Figure B.9. Systolic Blood Pressure 120 mmHg - ANF Representation

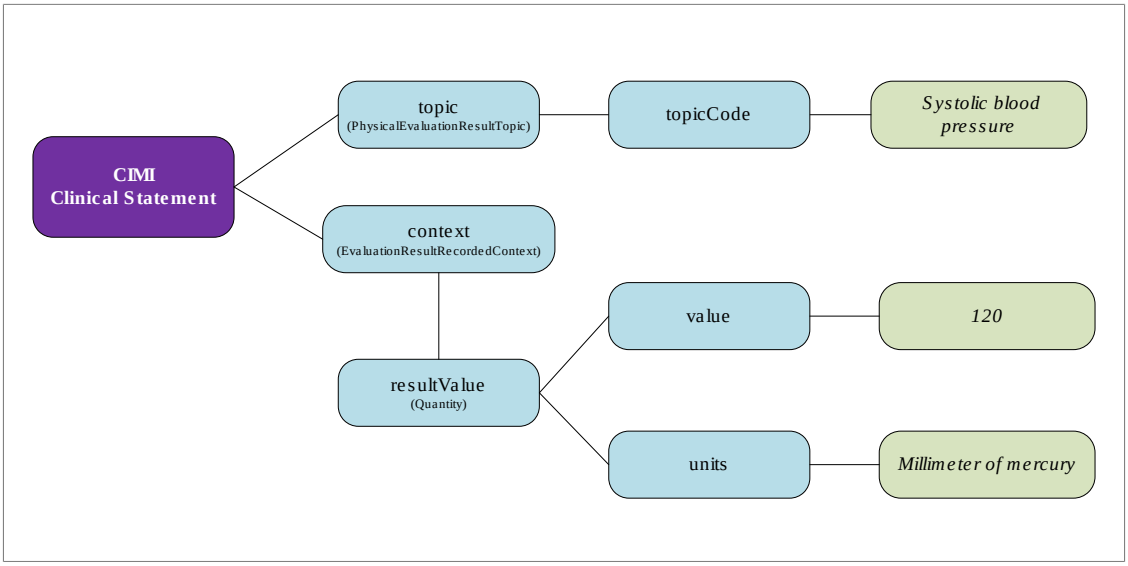

Figure B.10. Systolic Blood Pressure 120 mmHg - CIMI Representation

B.3.2. Complex Systolic Blood Pressure Statement

In this systolic blood pressure example the ANF model requires multiple statements to accurately capture all parts of the narrative clinical statement. The ANF model requires a clinical statement to be separated

if the clinical statement could stand on its own. For example, in the clinical statement "Systolic Blood Pressure 120 mmHg, taken on right brachial artery, using BP cuff adult size, patient in sitting position for at least 5 minutes, urinated not more than 30 minutes prior to measurement", the patient sitting position and urination parts of the statement are recorded as separate associated clinical statements since they could both be recorded as clinical statements on their own if they were not associated with the blood pressure clinical statement.

The ANF model is much more expressive and is able to capture the timing information for the position and urination that requires a separate precondition code to be created in the CIMI model.

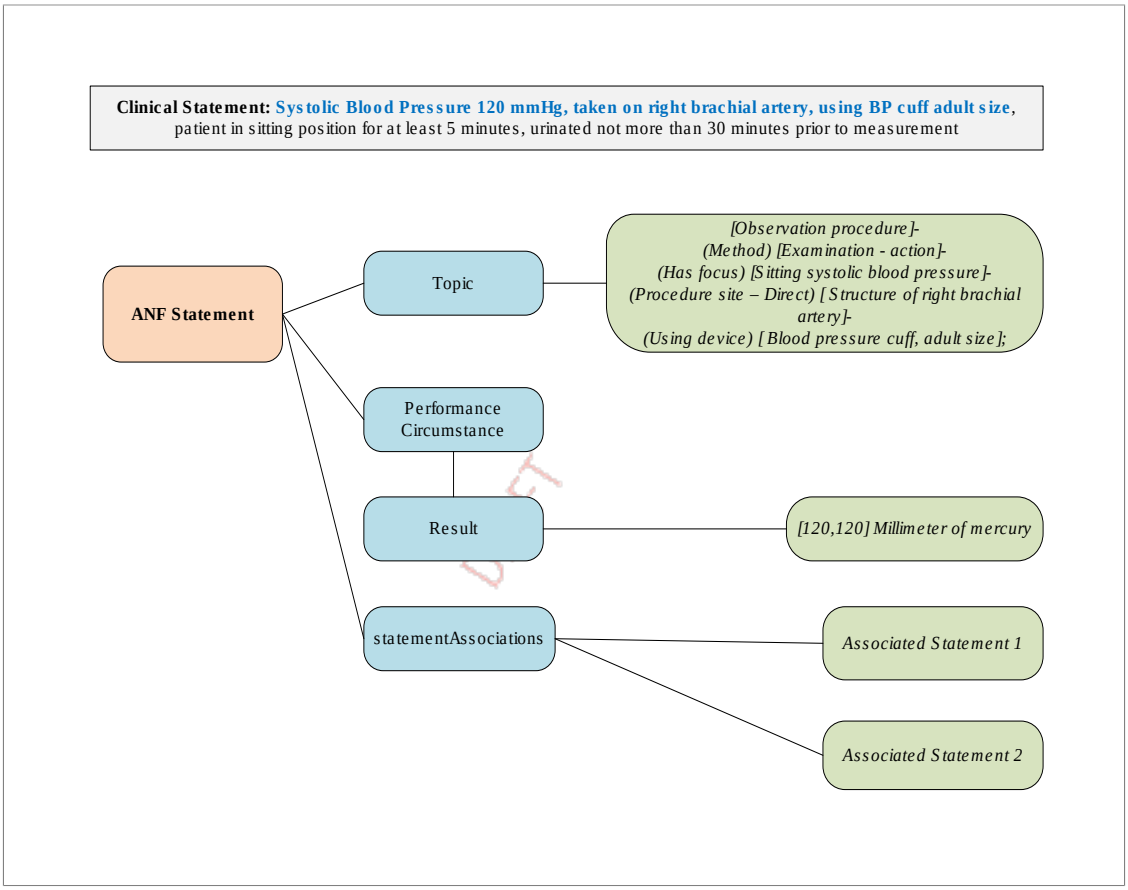

Figure B.11. Complex Systolic Blood Pressure - ANF Representation

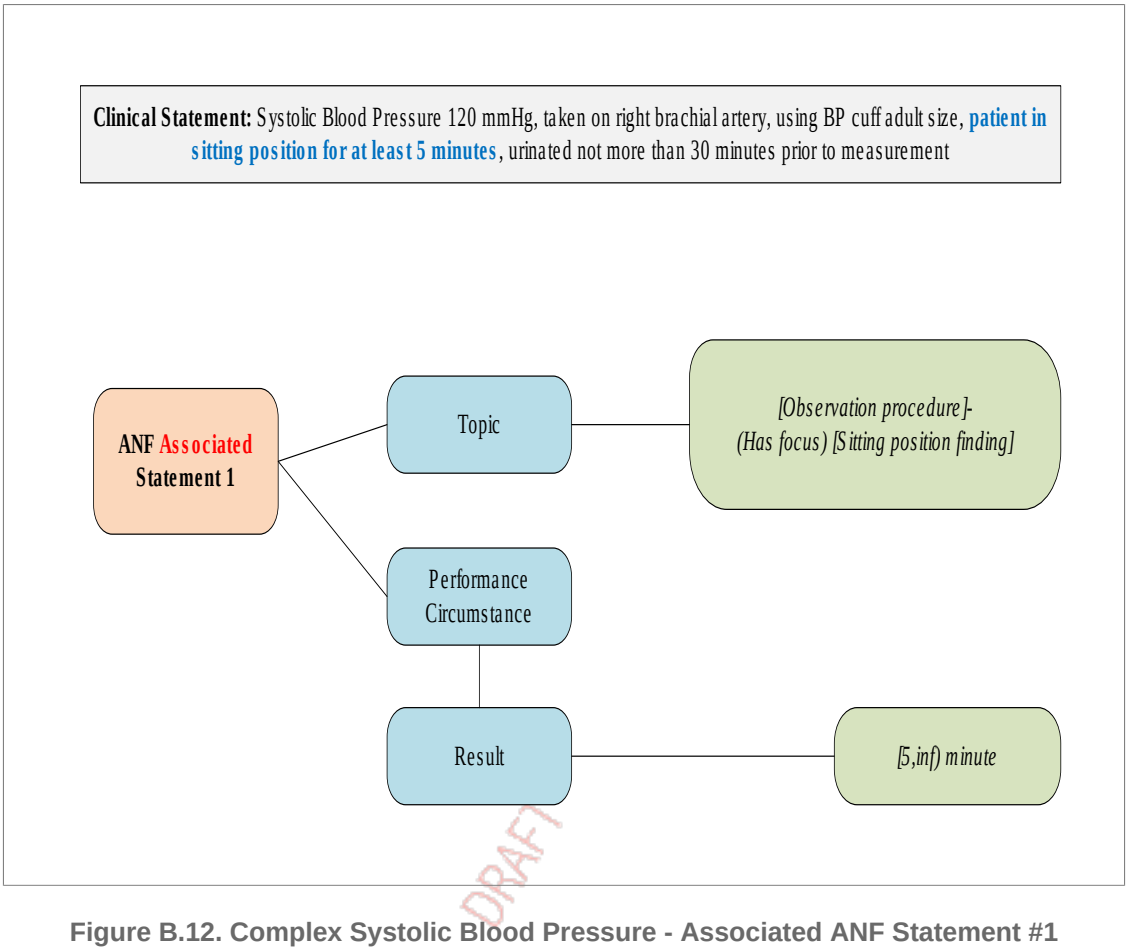

Figure B.12. Complex Systolic Blood Pressure - Associated ANF Statement #1

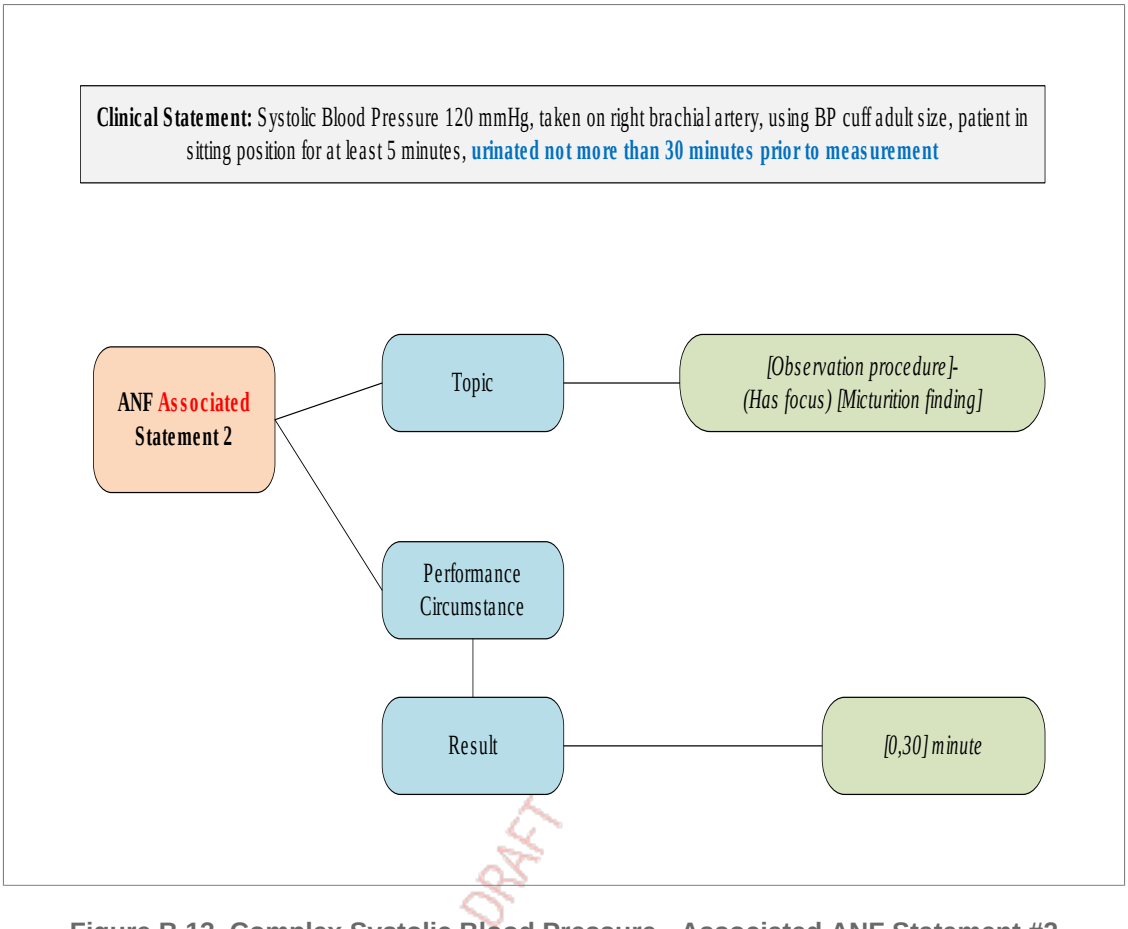

Figure B.13. Complex Systolic Blood Pressure - Associated ANF Statement #2

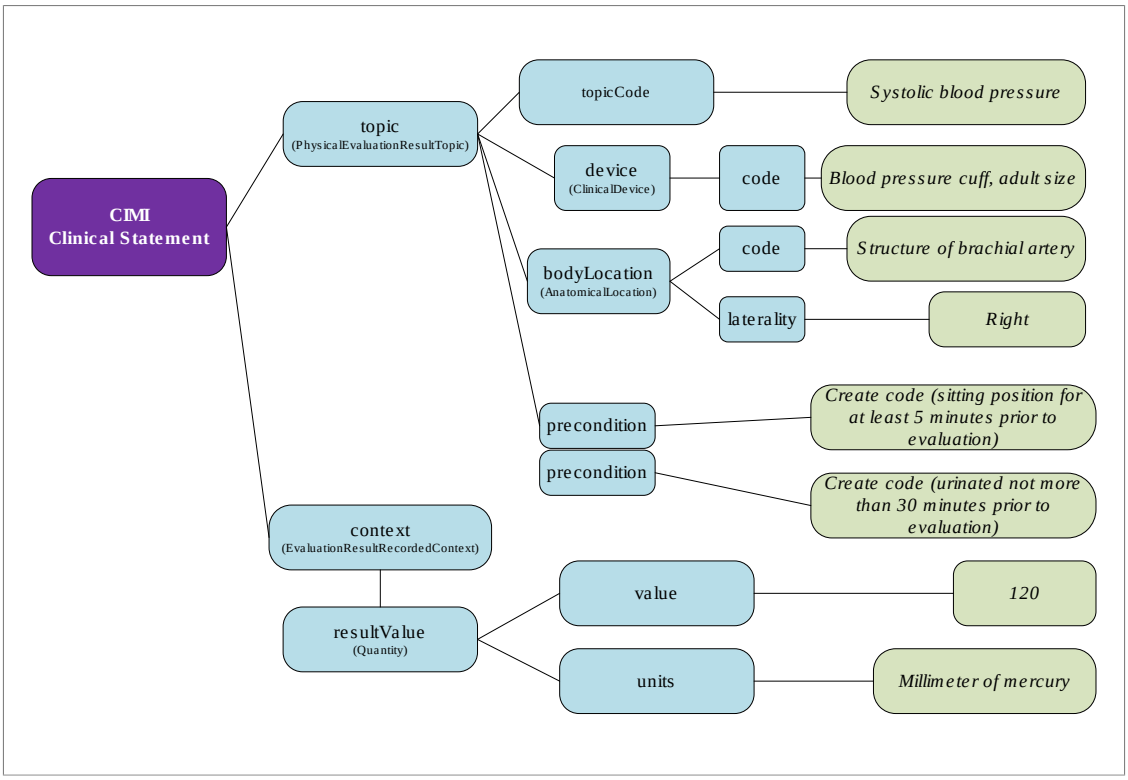

Figure B.14. Systolic Blood Pressure 120 mmHg, Taken on Right Brachial Artery, Using BP Cuff Adult Size, Patient in Sitting Position for at Least 5 Minutes, Urinated Not More than 30 Minutes Prior to Measurement - CIMI Representation

B.3.3. Diabetes Mellitus Statement

The Diabetes Mellitus example highlights the main difference between ANF and CIMI in the case of stating that a condition is present. In the case of ANF, since Result is not allowed to use a coded value it represents the presence as a lowerBound of 1 and an upperBound of infinite. Representing absence would be done with an upper and lower bound of zero.

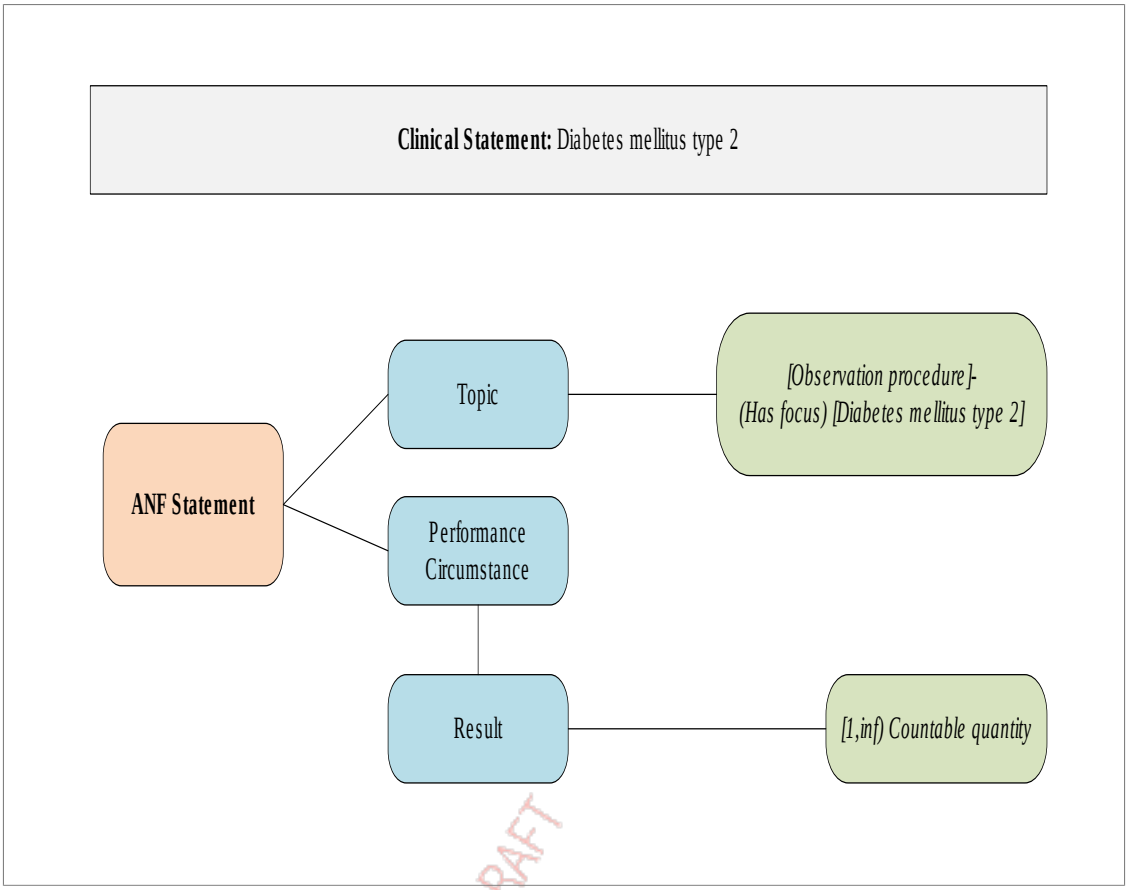

Figure B.15. Diabetes Mellitus - ANF Representation

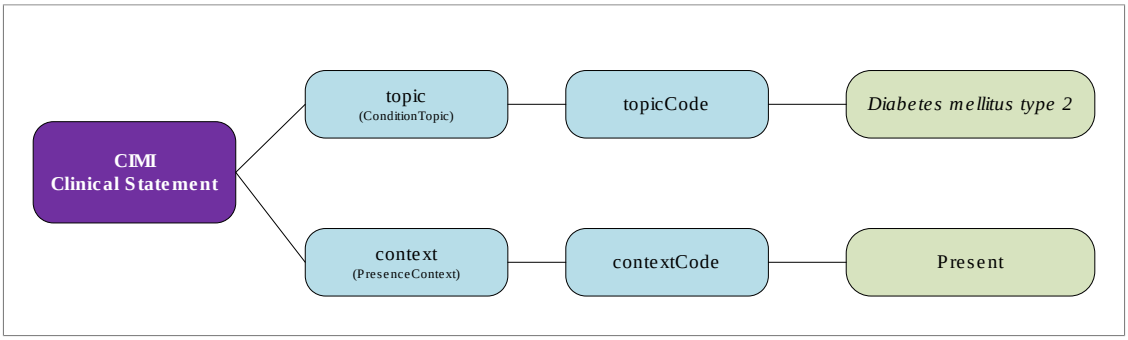

Figure B.16. Diabetes Mellitus Type 2 - CIMI Representation

C. Narratives

C.1. Request for Action Narratives

Example C.1. Radiology Request for Action Narratives

- X-ray chest to evaluate for heart failure now
- X-ray Knee-right to evaluate for psoriatic arthritis, routine
- Lumbar/Thoracic Spine CT with and without contrast

Example C.2. Pharmacy Request for Action Narratives

- Ibuprofen 400 mg tablet oral every 6 hours as needed for back pain; may increase dose frequency to one tablet every 4 hours 100 tablets 2 refills
- Ribavirin 200 mg capsule oral, take 2 capsules every morning and 3 capsules every evening
- Ribavirin 200 mg capsule oral, take 2 capsules every morning
- Ribavirin 200 mg capsule oral, 3 capsules every evening

Example C.3. Education Request for Action Narratives

- Advised to participate in tobacco cessation counseling once a week
- Food cross-reactivity education (routine)

Example C.4. Laboratory Request for Action Narratives

- Rheumatoid factor 1 time routine
- Brain natriuretic peptide STAT

Example C.5. Observation Request for Action Narratives

- Breast Screening Appointment on X Date

Example C.6. Cardiology Request for Action Narratives

- Cardiology referral
- Resting 12-lead electrocardiogram to evaluate for arrhythmia now
- Referral to cardiology to evaluate supraventricular tachycardia

Example C.7. Other Request for Action Narratives

- Proctoscopy with biopsy
- Hold insulin per Cardiac Catheterization Guidelines (just need an X start and stop time in relation to procedure)

C.2. Performance of Action Narratives

Example C.8. Radiology Performance of Action Narratives

- Lumbar/Thoracic Spine CT
- Lumbar/Thoracic Spine CT Myelogram Interpretation

Example C.9. Pharmacy Performance of Action Narratives

- Patient took one Acetaminophen 500 mg tablet by mouth for pain

Example C.10. Education Performance of Action Narratives

- Patient was provided with education on diabetes

Example C.11. Laboratory Performance of Action Narratives

-

Example C.12. Observation Performance of Action Narratives

- History of Cocaine Use
- First degree relatives with ovarian cancer
- Blue Eye Color
- Dot blot hemorrhage Present
- Family history of breast cancer
- Systolic Blood Pressure 120 mmHg
- Systolic Blood Pressure 180 mmHg, normalRange (90-120), health risk critical
- Systolic Blood Pressure 120 mmHg, taken on right brachial artery, using BP cuff adult size, patient in sitting position for at least 5 minutes, urinated not more than 30 minutes prior to measurement
- Pulse Rate 68 bpm, taken by pulse oximeter
- Diabetes mellitus type 2
- Diabetes mellitus type 2 Absent
- Had an appendectomy 3-4 years ago
- Nausea and vomiting
- Ischemic stroke without coma
- Akinetic seizure without atonia
- Incontinence without sensory awareness
- Blister with infection
- Patient reports experiencing anxiety and fear

- Pleural empyema with fistula

Example C.13. Cardiology Performance of Action Narratives

•

Example C.14. Other Performance of Action Narratives

- Insulin placed on hold 24 hours prior to catheterization
- Columbia-Suicide Severity Rating Scale (C-SSRS) Screen Negative Result
- Candidate for Osteoporosis Screening
- Positive screen for fall risk
- Negative screen for PTSD and Depression

D. ANF Examples

D.1. Examples of Performance Clinical Statements

For the examples in the following chapters, the focus has been to illustrate the ANF Model, using easy and intuitive examples, rather than focus on the correctness of the modeling. The modeling within the post-coordinated expressions of the "topic" could potentially be done in different ways.

D.1.1. Blood Pressure Measurement

<table>
<tr><td colspan="2">Narrative: Systolic blood pressure 120 mmHg; taken on right brachial artery using adult blood pressure cuff; patient in sitting position for at least 5 minutes; urinated not more than 30 minutes prior to measurement

Statement type:[Performance]

Subject of info: [Subject of record]

Authors: [Healthcare professional]

Topic: [Observation procedure]-
(Method) [Examination - action]-
(Has focus) [On examination - Systolic blood pressure reading]-
(Procedure site – Direct) [Structure of right brachial artery]-
(Using device) [Blood pressure cuff, adult size];</td></tr>
<tr><td rowspan="2">Circumstance:</td><td>Performance Circumstance</td></tr>
<tr><td>• Timing: [ISO 8601 date/time format]
• Purposes: Ø
• Triggers: Ø
• Participants: [Subject of record]
• Priority: Ø</td></tr>
<tr><td></td><td>• Result:
  • [120,120] Millimeter of mercury</td></tr>
<tr><td colspan="2">Associations:

[UUID] (Table: Associated Clinical Statement 1)</td></tr>
</table>

*[UUID]**(Table: Associated Clinical Statement 2)*** Statement time: *[ISO 8601 date/time format]* Stamp coordinate: *[Solor Module]* , *[Release Path]* , 2007-04-05T14:30Z Statement id: *[UUID]* Subject of record ID:*[UUID]*

Table D.1. Performance Clinical Statement

Narrative: Arterial blood pressure 120 mmHg; taken on right brachial artery using adult blood pressure cuff; ***patient in sitting position for at least 5 minutes***; urinated not more than 30 minutes prior to measurement Statement type:*[Performance]* Subject of info: *[Subject of record]* Authors: *[Healthcare professional]* Topic: *[Observation procedure]*- *(Has focus) [Sitting position finding]*	
Circumstance:	Performance Circumstance • Timing: ≥ 5 min. prior to statement time • Purposes: Ø • Triggers: Ø • Participants: *[Subject of record]* • Priority: Ø
	• Result: • [5,inf) minute
Associations: *[UUID]* Statement time: *[ISO 8601 date/time format]* Stamp coordinate: *[Solor Module]* , *[Release Path]* , 2007-04-05T14:30Z Statement id: fc48551f-876a-42c1-b179-3169e3748332 Subject of record ID:*[UUID]*	

Table D.2. Associated Clinical Statement 1

<table>
<tr><td colspan="2">Narrative: Arterial blood pressure 120 mmHg; taken on right brachial artery using adult blood pressure cuff; patient in sitting position for at least 5 minutes; urinated not more than 30 minutes prior to measurement

Statement type:[Performance]

Subject of info: [Subject of record]

Authors: [Healthcare professional]

Topic: [Observation procedure]-

(Has focus) [Micturition finding]</td></tr>
<tr><td rowspan="2">Circumstance:</td><td>Performance Circumstance</td></tr>
<tr><td>• Timing: ≤ 30 min. prior to statement time
• Purposes: Ø
• Triggers: Ø
• Participants: [Subject of record]
• Priority: Ø</td></tr>
<tr><td></td><td>• Result:
  • [0,30] minute</td></tr>
<tr><td colspan="2">Associations: [UUID]

Statement time: [ISO 8601 date/time format]

Stamp coordinate: [Solor Module] , [Release Path] , 2007-04-05T14:30Z, Statement id: [UUID]

Statement id: df478857-2eae-40b2-909f-68ef0d0b9eb5

Subject of record ID:[UUID]</td></tr>
</table>

Table D.3. Associated Clinical Statement 2

D.1.2. Pulse Rate Measurement

<table>
<tr><td>Narrative: Pulse Rate 68 bpm, taken by pulse oximeter

Statement type:[Performance]

Subject of info: [Subject of record]

Authors: [Healthcare professional]</td></tr>
</table>

Topic: *[Observation procedure]-* *(Method) [Examination - action]-* *(Has focus) [On examination - pulse rate]-* *(Using device) [Pulse oximeter];*	
Circumstance:	Performance Circumstance
	• Timing: *[ISO 8601 date/time format]* • Purposes: Ø • Triggers: Ø • Participants: *[Subject of record]* • Priority: Ø
	• Result: • [68,68] Beats/minute
Associations: Ø Statement time: *[ISO 8601 date/time format]* Stamp coordinate: *[Solor Module]* , *[Release Path]* , 2007-04-05T14:30Z, Statement id: *[UUID]* Subject of record ID:[*UUID*]	

Table D.4. Performance Clinical Statement

D.1.3. Patient History

Narrative: ***Patient has thromboembolism history*** Statement type:*[Performance]* Subject of info: *[Subject of record]* Authors: *[Healthcare professional]* Topic: *[Observation procedure]-* *(Method) [Examination - action]-* *(Has focus) [Thromboembolic disorder];*	
Circumstance:	Performance Circumstance
	• Timing Value: [1, inf) ISO 8601 prior to statement time • Purposes: Ø

	• Triggers: Ø • Participants: *[Subject of record]* • Priority: Ø
	• Result: • [1,inf) Countable quantity
Associations: Ø Statement time: *[ISO 8601 date/time format]* Stamp coordinate: *[Solor Module]* , *[Release Path]* , 2007-04-05T14:30Z, Statement id: *[UUID]* Subject of record ID:[*UUID*]	

Table D.5. Performance Clinical Statement

D.1.4. Condition Present

Narrative: ***Diabetes Mellitus present*** Statement type:*[Performance]* Subject of info: *[Subject of record]* Authors: *[Healthcare professional]* Topic: *[Observation procedure]-* *(Method) [Examination - action]-* *(Has focus) [Diabetes mellitus];*	
Circumstance:	Performance Circumstance
	• Timing: *[ISO 8601 date/time format]* • Purposes: Ø • Triggers: Ø • Participants: *[Subject of record]* • Priority: Ø
	• Result: • [1,inf) Countable quantity
Associations: Ø Statement time: *[ISO 8601 date/time format]* Stamp coordinate: *[Solor Module]* , *[Release Path]* , 2007-04-05T14:30Z, Statement id: *[UUID]*	

Subject of record ID:[*UUID*]

Table D.6. Performance Clinical Statement

D.1.5. Condition Not Present

Narrative: ***Diabetes Mellitus not present*** Statement type:*[Performance]* Subject of info: *[Subject of record]* Authors: *[Healthcare professional]* Topic: *[Observation procedure]-* *(Method) [Examination - action]-* *(Has focus) [Diabetes mellitus];*	
Circumstance:	Performance Circumstance • Timing: *[ISO 8601 date/time format]* • Purposes: Ø • Triggers: Ø • Participants: *[Subject of record]* • Priority: Ø
	• Result: • [0,0] Unit of time
Associations: Ø Statement time: *[ISO 8601 date/time format]* Stamp coordinate: *[Solor Module]* , *[Release Path]* , 2007-04-05T14:30Z, Statement id: *[UUID]* Subject of record ID:[*UUID*]	

Table D.7. Performance Clinical Statement

D.1.6. Three dot blot hemorrhages

Narrative: ***Three dot blot hemorrhages*** Statement type:*[Performance]*

Subject of info: *[Subject of record]* Authors: *[Healthcare professional]* Topic: *[Observation procedure]-* *(Method) [Examination - action]-* *(Has focus) [Deep retinal hemorrhage];*	
Circumstance:	Performance Circumstance
	• Timing: *[ISO 8601 date/time format]* • Purposes: Ø • Triggers: Ø • Participants: *[Subject of record]* • Priority: Ø
	• Result: • [3,3] Number
Associations: Ø Statement time: *[ISO 8601 date/time format]* Stamp coordinate: *[Solor Module]* , *[Release Path]* , 2007-04-05T14:30Z, Statement id: [*UUID*] Subject of record ID:[*UUID*]	

Table D.8. Performance Clinical Statement

D.1.7. Dot blot hemorrhage present

Narrative: ***Dot blot hemorrhage present*** Statement type:*[Performance]* Subject of info: *[Subject of record]* Authors: *[Healthcare professional]* Topic: *[Observation procedure]-* *(Method) [Examination - action]-* *(Has focus) [Deep retinal hemorrhage];*	
Circumstance:	Performance Circumstance
	• Timing: *[ISO 8601 date/time format]*

	• Purposes: Ø • Triggers: Ø • Participants: *[Subject of record]* • Priority: Ø
	• Result: • [1,inf) Countable quantity
Associations: Ø Statement time: *[ISO 8601 date/time format]* Stamp coordinate: *[Solor Module]* , *[Release Path]* , 2007-04-05T14:30Z, Statement id: [*UUID*] Subject of record ID:[*UUID*]	

Table D.9. Performance Clinical Statement

D.1.8. Family History

Narrative: ***Family history (mother) of colon cancer*** Statement type:*[Performance]* Subject of info: *[Mother of subject]* Authors: *[Healthcare professional]* Topic: *[Observation procedure]-* *(Method) [Examination - action]-* *(Has focus) [Malignant neoplasm of colon];*	
Circumstance:	Performance Circumstance
	• Timing: [1, inf) ISO 8601 prior to statement time • Purposes: Ø • Triggers: Ø • Participants: *[Subject of record]* • Priority: Ø
	• Result: • [1,inf) Countable quantity
Associations: Ø Statement time: *[ISO 8601 date/time format]*	

Stamp coordinate: *[Solor Module]* , *[Release Path]* , 2007-04-05T14:30Z, Statement id: [*UUID*] Subject of record ID:[*UUID*]

Table D.10. Performance Clinical Statement

D.2. Examples of Modeling Request Clinical Statements

D.2.1. Medication Order

Narrative: ***Request for administration of Ibuprofen 400 mg tablet oral every 6 hours as needed for back pain; may increase dose frequency to one tablet every 4 hours*** Statement type:*[Request]* Subject of info:*[Subject of record]* Authors: *[Healthcare professional]* Topic: *[Procedure]*- *(Method) [Administration - action] (Direct substance) [Ibuprofen 400 MG Oral Tablet]* *(Route of administration) [Oral]*	
Circumstance:	RequestCircumstance: • timing: *[ISO 8601 date/time format]* • purpose: *[Backache]* • requestedParticipant: *[Subject of record]* • priority: *[Routine]*
	• repetition: • eventFrequency: [4,6] hour
	• requestedResult
Associations: Ø Statement time: *[ISO 8601 date/time format]* Stamp coordinate: *[Solor Module]* , *[Release Path]* , 2007-04-05T14:30Z, Statement id: [*UUID*] Subject of record ID:[*UUID*]	

Table D.11. Request Clinical Statement

D.2.2. Radiology Order

<table>
<tr><td colspan="2">Narrative: Request for x-ray chest to evaluate chest pain (routine)

Statement type:[Request]

Subject of info:[Subject of record]

Authors: [Healthcare professional]

Topic: [Plain chest X-ray]</td></tr>
<tr><td rowspan="2">Circumstance:</td><td>Request Circumstance</td></tr>
<tr><td>• timing: [ISO 8601 date/time format]
• purpose: [Assessment of chest pain]
• requestedParticipant: [Subject of record]
• priority: [Routine]</td></tr>
<tr><td></td><td>• requestedResult</td></tr>
<tr><td colspan="2">Associations: Ø

Statement time: [ISO 8601 date/time format]

Stamp coordinate: [Solor Module] , [Release Path] , 2007-04-05T14:30Z, Statement id: [UUID]

Subject of record ID: [UUID]</td></tr>
</table>

Table D.12. Request Clinical Statement

D.2.3. Medication Order

<table>
<tr><td>Narrative: Request for administration of nitroglycerin 0.4 mg tablet sub-lingual every 5 minutes as needed for chest pain; maximum 3 tablets (routine).

Statement type:[Request]

Subject of info:[Subject of record]

Authors: [Healthcare professional]

Topic: [Procedure]-

(Method) [Administration - action] (Direct substance) [Nitroglycerin 400micrograms tablet]

(Route of administration) [Oral]</td></tr>
</table>

(Method) [Administration - action] (Direct substance) [Ibuprofen 400 MG Oral Tablet] *(Route of administration) [Oral]*	
Circumstance:	Request Circumstance
	• Timing: *[ISO 8601 date/time format]* • Purpose: *[Chest pain]* • Priority: *[Routine]* ***Frequency*** eventFrequency: *[5,15] min* • resolution: *5*
	• requestedResult: *[1,1] Conventional release sublingual tablet* • resolution: *1*
Associations: *Ø* Statement time: *[ISO 8601 date/time format]* Stamp coordinate: *[Solor Module]* , *[Release Path]* , 2007-04-05T14:30Z, Statement id: [*UUID*] Subject of record ID:[*UUID*]	

Table D.13. Request Clinical Statement

D.3. Examples of Modeling C-CDA Entries Based on ANF

D.3.1. Summary of Care

C-CDA Category/Entry	**Modeling**
Reason for referral • Pulmonary Function Tests	**Statement type:***[Request]* **Topic:***[23426006 |Measurement of respiratory function]-* *(260686004 |Method) [129266000 |Measurement – action]*
Allergies, Adverse Reactions and Alerts • Allergen: Penicillin G • Reaction: Hives • Reaction severity: Severe	**Statement type:***[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [294499007 |Allergy to benzylpenicillin]*

	Associated statement: **Statement type:***[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [247472004 |Weal]-* *(42752001 |Due to) [294499007 |Allergy to benzylpenicillin]-* *(246112005 |Severity) [24484000 |Severe (severity modifier)]*
Problem list • Costal Chondritis • Asthma	**Statement type:** *[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [64109004 |Costal chondritis]*
	Statement type: *[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [195967001 |Asthma]*
Social History • Never smoked	**Statement type:***[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [266919005 |Never smoked tobacco]*
Immunizations • Influenza virus vaccine: completed	**Statement type:***[Performance]* **Topic:** [*86198006 |Influenza vaccination]-* **Result status:** *[255594003 |Complete]*
Medications • Albuterol 0.09 mg ACTUAT	**Statement type:***[Performance]* **Topic:** [*416118004 |Administration]-* *(260686004 |Method) [129445006 |Administration – action]-* *(363701004 |Direct substance) [Rx; 329498 Albuterol 0.09 MG/ACTUAT]*

Table D.14. Summary of Care 1

C-CDA Category/Entry	Modeling
Functional and Cognitive Status • Functional status: No impairment • Cognitive status: No impairment	**Statement type:** *[Performance]* **Topic:***[5751000205109|Observation procedure]-* *(363702006 |Has focus) [118228005 |Functional finding]-* *(363714003 |Interprets) [246464006 |Function]-* *(363713009 |Has interpretation) [17621005 | Normal];*
	Statement type: *[Performance]* **Topic:***[5751000205109|Observation procedure]-* *(363702006 |Has focus) [373930000 |Cognitive function]-* *(363714003 |Interprets) [311465003 |Cognitive functions]-* *(363713009 |Has interpretation) [17621005 | Normal];*
Vital signs • Height: 70 in • Weight: 195 lb. • Body Mass Index (calculated): 28 • BP systolic: 155 mmHg • BP diastolic: 92 mmHg	**Statement type:** *[Performance]* **Topic:** [*14456009 |Measuring height of patient]-* *(260686004 |Method) [129266000 |Measurement - action]* **Result:** *70 [258677007 |Inch]*
	Statement type: *[Performance]* **Topic:** [*39857003 |Weighing patient]-* *(260686004 |Method) [129266000 |Measurement - action]* **Result:** *195 [258693003 |pounds]*
	Statement type: *[Performance]* **Topic:** [*698094009 |Measurement of body mass index]-* *(260686004 |Method) [129266000 |Measurement - action]*

	Result: *28*
	Statement type: *[Performance]* **Topic:** *[5751000205109|Observation procedure]-* *(260686004|Method) [302199004|Examination - action]-* *(363702006 |Has focus) [163030003 |On examination - Systolic blood pressure reading];* **Result:** *155 [259018001 |Millimeter of mercury]*
	Statement type: *[Performance]* **Topic:** *[5751000205109|Observation procedure]-* *(260686004|Method) [302199004|Examination - action]-* *(363702006 |Has focus) [163031004 |On examination - Diastolic blood pressure reading]* **Circumstance:** **Result:** *92 [259018001 |Millimeter of mercury]*
Results • CO2 27 mmol/L	**Statement type:***[Performance]* **Topic:** [*38007001 |Carbon dioxide measurement]* **Circumstance:** **Result:** *27 [258813002 |Millimole/liter]*
Plan of Care • Goal: Weight loss: Patient education: Diet counseling	**Statement type:** *[Performance]* **Topic:** *[266724001 |Weight-reducing diet education]*
• Asthma management: Patient education: Resources and instructions	**Statement type:** *[Performance]* **Topic:** *[698605001 |Education about asthma self management]*

Table D.15. Summary of Care 2

D.3.2. Patient Chart Summary (Excerpt)

C-CDA Category/Entry	Modeling

Advance Directives • Do not resuscitate	**Statement type:***[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [304253006 |Not for resuscitation]*
Allergies, Adverse Reactions and Alerts • Allergen: Penicillin • Reaction: Nausea	**Statement type:***[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [91936005 |Allergy to penicillin]*
	Associated statement: **Statement type:***[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [422587007 |Nausea]-* *(42752001 |Due to) [91936005 |Allergy to penicillin];*
Problem list • Chest pain • Angina	**Statement type:** *[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [29857009 |Chest pain]*
	Statement type: *[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [194828000 |Angina]*
Social History • Former smoker • Consumes 12 alcoholic drinks/day	**Statement type:** *[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [8517006 |Ex-smoker]*
	Statement type: *[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [228319007 |Drinks alcohol daily]-* *(363714003 |Interprets) [160573003 |Alcohol intake];*

	Result: 12 [258950000 |Unit/day]
Results • Hemoglobin 13.2 g/dl • Hematocrit 33.5%	**Statement type:** *[Performance]* **Topic:** [*104718002 |Hemoglobin, free measurement]-* **Result:** 13.2 *[258795003 |Gram/deciliter]*
	Statement type: *[Performance]* **Topic:** [*28317006 |Hematocrit determination]-* **Result:** 33.5 *[118582008 |Percent (property]*

Table D.16. Patient Chart Summary 1

D.4. Examples of Modeling KNARTs Based on ANF

D.4.1. Atrial Fibrillation / Atrial Flutter Order Set (Excerpt)

Orderable Procedure/Narrative	Modeling
Referral to cardiology to evaluate atrial fibrillation/ atrial flutter	**Statement type:***[Request]* **Topic:** [183519002 |Referral to cardiology service] **Purpose:** *[386053000 |Evaluation procedure]-* *(363702006 |Has focus) [195080001 |Atrial fibrillation and flutter]*
Resting 12-lead electrocardiogram to evaluate arrhythmia	**Statement type:***[Request]* **Topic:** [*447113005 |12 lead electrocardiogram at rest]* **Purpose:** *[386053000 |Evaluation procedure]-* *(363702006 |Has focus) [698247007 |Cardiac arrhythmia]*
Echocardiogram to evaluate left ventricular function	**Statement type:***[Request]* **Topic:** [*40701008 |Echocardiography]*

	Purpose: *[386053000 |Evaluation procedure]-* *(363702006 |Has focus) [366188009 |Finding of left ventricular function]*
X-ray chest to evaluate heart failure STAT	**Statement type:***[Request]* **Topic:** [*399208008 |Plain chest X-ray]* **Purpose:** *[386053000 |Evaluation procedure]-* *(363702006 |Has focus) [84114007 |Heart failure]* **Priority:** *[49499008 |Stat]*
Basic metabolic panel	**Statement type:***[Request]* **Topic:** [*1421000205106 |Basic metabolic panel]*
Complete blood count ROUTINE	**Statement type:***[Request]* **Topic:** [*26604007 |Complete blood count]* **Priority:** *[50811001 |Routine]*

Table D.17. Artial Fabrillation 1

Orderable Procedure/Narrative	**Modeling**
Metoprolol tartrate 50 mg tablet oral daily 2 times	**Statement type:***[Request]* **Topic:** *[416118004 |Administration]-* *(260686004 |Method) [[129445006 | Administration – action]-* *(363701004 |Direct substance) [318475005 | Product containing precisely metoprolol tartrate 50 milligram/1 each conventional release oral tablet]-* *(410675002 |Route of administration) [[260548002 |Oral];* **Requested Result: 1** *[421026006 |Oral tablet]* **Frequency: 2** *[258703001 |day]*

Table D.18. Artial Fabrillation 2

D.4.2. Diagnostic Breast Imaging Documentation Template (Excerpt)

Observation/Narrative	Modeling
Screening Mammogram	**Statement type:***[Performance]* **Topic:** [24623002 |Screening mammography]
Mammogram Interpretation Normal	**Statement type:***[Performance]* **Topic:** [*370851004 |Evaluation of diagnostic study results]-* *(363702006 |Has focus) [71651007 | Mammography]* **Result Status:** *[17621005 |Normal]*
Nipple discharge	**Statement type:***[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [54302000 |Discharge from nipple]*
Nipple discharge is normal lactation	**Statement type:***[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [54302000 |Discharge from nipple]* *(42752001 |Due to) [82374005 |Lactation normal]*
Breast Skin Changes	**Statement type:***[Performance]* **Topic:** [*5751000205109|Observation procedure]-* *(363702006 |Has focus) [115951000119105 | Breast symptom of change in skin]*
First degree relative is a BRCA mutation carrier	**Statement type:***[Performance]* **Subject of Information:** *[125678001 |First degree blood relative]* **Topic:** [*5751000205109|Observation procedure]-*

	(363702006 |Has focus) [445333001 |Breast cancer genetic marker of susceptibility positive]

Table D.19. Diagnostic Breast Imaging Documentation Template 1