

Terminology and Ontology Development for Semantic Annotation: A Use Case on Sepsis and Adverse Events

Melissa Y. Yan ^{a,*}, Lise Tuset Gustad ^{b,c,d}, Lise Husby Høvik ^{c,e} and Øystein Nytrø ^a

^a *Department of Computer Science, Norwegian University of Science and Technology, Trondheim, Norway*

E-mails: melissa.yan@ntnu.no, nytroe@ntnu.no

^b *Faculty of Nursing and Health Sciences, Nord University, Levanger, Norway*

E-mail: lise.t.gustad@nord.no

^c *Department of Circulation and Medical Imaging, Norwegian University of Science and Technology, Trondheim, Norway*

E-mails: lise.t.gustad@ntnu.no, lise.hovik@ntnu.no

^d *Department of Medicine, Levanger Hospital, Nord-Trøndelag Hospital Trust, Levanger, Norway*

E-mail: lise.gustad@hnt.no

^e *Clinic of Anaesthesia and Intensive Care, St. Olavs hospital, Trondheim University Hospital, Trondheim, Norway*

E-mail: lise.husby.hovik@stolav.no

Abstract. Annotations enrich text corpora and provide necessary labels for natural language processing studies. To reason and infer underlying implicit knowledge captured by labels, an ontology is needed to provide a semantically annotated corpus with structured domain knowledge. Utilizing a corpus of adverse event documents annotated for sepsis-related signs and symptoms as a use case, this paper details how a terminology and corresponding ontology were developed. The Annotated Adverse Event Note Terminology (AAENOTE) represents annotated documents and assists annotators in annotating text. In contrast, the complementary Catheter Infection Indications Ontology (CIIO) is intended for clinician use and captures domain knowledge needed to reason and infer implicit information from data. The approach taken makes ontology development understandable and accessible to domain experts without formal ontology training. AAENOTE, CIIO, and their corresponding SPARQL queries used to answer competency questions are available at https://github.com/melissayan/aaenote_and_ciio.

Keywords: ontology development, clinical knowledge representation and reasoning, semantic annotation, sepsis, adverse events

1. Introduction

Many natural language processing (NLP) studies rely on annotated corpora to create models for text classification, text extraction, named entity recognition, question answering, summarization, and text generation. Often, semantic annotation is done to capture domain knowledge within text. Annotated corpora are frequently generated by annotators based on an anno-

tation guideline, which provides the standard and rules for how to label text using specified terms. This annotation guideline is usually similar to a terminology, unless the corpus was annotated using an ontology. To further enrich an annotated corpus by capturing, reasoning, and inferring the underlying associated domain knowledge, an ontology is needed.

This paper provides a detailed and concrete description of the methodology utilized for ontology development of an annotated corpus based on a use case from

*Corresponding author. E-mail: melissa.yan@ntnu.no.

the clinical domain. The main contributions presented are:

1. Describing the development process for constructing a terminology that can represent an annotated corpus. Specifically, a terminology for indexing annotated adverse event (AE) documents.
2. Presenting the development process for the terminology's corresponding ontology, which represents domain knowledge and allows inferring implicit knowledge in a specific domain. The corresponding ontology in the use case represents clinical domain knowledge specifically for annotated catheter-related and infection-related signs in AE documents.
3. Releasing a terminology and ontology that can be applicable to identifying and reasoning about sepsis in an AE corpus.

This paper significantly extends [1], which only presented the initial stages of translating the annotation guideline into an ontology, but lacked results. Additionally, individuals in the terminology were obtained from the annotation guideline development and annotated corpus in [2].

Based on the presented use case in Section 3 and objective in Section 4, an Annotated Adverse Event Note Terminology (AAENOTE) and corresponding Catheter Infection Indications Ontology (CIIO) were developed. Section 6 details the terminology construction and development process to represent annotated documents, and Section 7 presents the results and evaluations for the AAENOTE. To address shortcomings in the terminology for annotated documents, Section 8 describes the ontology development process for domain knowledge representation of documented content, and Section 9 presents the results, and evaluations for the CIIO. Finally, Section 10 discusses the findings, limitations, representations, accessibility, and utility.

2. Related Work

Many studies focus on the relationship between annotation, tagging, and ontologies for NLP development. These studies include annotating corpora and NLP extraction and classification tasks. Below are some studies that have shared their findings, issues, and possible solutions.

In the 2010 i2b2/VA workshop on NLP challenge, three tasks were evaluated. The first task was to extract medical concepts from unannotated patient re-

ports (i.e., extract medical problems, treatments, and tests), which was difficult because of concept boundaries. Another task which proved unproblematic was to assign assertion types to annotated medical problem concepts (i.e., extract negation and uncertainty of conditional and hypothetical medical problems to classify present, absent, or possible medical concepts). And the third task was to assign relations between medical problems, tests, and treatments (i.e., relation classification of concepts in a sentence) [3], which was the most difficult due to language complexity and missing explicit contextual information. To deal with the lack of explicit contextual information needed for relationship classification, it was suggested domain knowledge may help [3].

Annotated using the Uberon multi-species anatomical ontology [4], the Colorado Richly Annotated Full-Text (CRAFT) Corpus is a resource for NLP development which is also semantically annotated with concepts from eight Open Biomedical Ontologies (OBO) and terminologies [5, 6]. While annotating with the OBOs, they discovered that the OBOs are not developed for annotation because there are overlapping terms within the different OBOs, context-specific definitions, semantic ambiguities, and some OBOs do not follow the OBO Foundry principle of using relations from the OBO Relation Ontology (RO) [7] to link concepts [8]. To improve OBOs for semantic annotation of biomedical documents, the researchers proposed desirable ontology implementations such as, but not limited to, integrating overlapping OBOs terms, resolving ontology-specific ambiguities, and expanding relations [8].

A study comparing how anatomy ontologies are used for annotations discovered annotation and ontology issues [9]. Annotations from three public datasets were compared to anatomical terms in the Foundational Model of Anatomy (FMA) [10, 11] and Uberon [4] ontologies using the Zooma¹ and Ontology Mapper² software tools. Manual and semi-automated preprocessing was done to normalize terms, but there were few matches between the ontologies and annotations, mainly because of strict matching. Additionally, the user-provided annotation labels resulted in mismatches, such as annotating a phrase with multiple ontology terms or using an abbreviation or adjective for an anatomical part instead of using the anatomical on-

¹<https://www.ebi.ac.uk/spot/zooma/>

²<http://www.ebi.ac.uk/efo/tools>

1 tology term. Ontology issues include missing anatomical
 2 synonyms used by the annotators and differing
 3 anatomical terms in the ontologies because the ontologies
 4 are designed for different purposes and made by
 5 different design decisions. The study concluded that
 6 mapping terms to an ontology requires a large amount
 7 of time, effort, and manual curation. Further, an ontology's
 8 design decisions and scope will affect users trying
 9 to match annotations to an ontology, and ontologies
 10 must be used to understand their potential.

11 The Unified Medical Language System (UMLS) is
 12 a collection of standard biomedical terminology [12],
 13 and it has been used to process text by extracting
 14 concepts, relations, and knowledge (i.e., link or
 15 annotate text with standard terminology) [13]. A software
 16 capable of finding and linking biomedical text to
 17 terminology concepts in the UMLS Metathesaurus is
 18 MetaMap [14]. However, the developers of MetaMap
 19 mention that improvement is required to improve the
 20 detection of similar names, acronyms, and abbreviations
 21 and to resolve ambiguities by possibly distinguishing
 22 concepts using word sense disambiguation.

23 3. Use Case

24 As the most commonly used medical device in hospitals,
 25 peripheral intravenous catheters (PIVCs), are
 26 inserted into the peripheral vein to administer intravenous
 27 (IV) fluids, IV medications, and blood transfusions [15].
 28 Improper management of PIVC or the infusions connected
 29 to the PIVC can lead to phlebitis, which is either infectious,
 30 mechanical, or chemical inflammation of the vein [16–18].
 31 Independent of cause, all PIVC phlebitis share many
 32 symptoms like redness and swelling near a patient's
 33 infusion insertion site across infectious, mechanical, or
 34 chemical phlebitis, making it difficult to distinguish.
 35 Further, all PIVC-related phlebitis causes adverse events
 36 like significant pain, PIVC failure that delays treatment,
 37 and compromising future venous access. Infectious
 38 phlebitis may lead to bloodstream infection (BSI) due to:
 39 1. migration of bacteria at the insertion site, 2. bacteria
 40 migrating through the catheter tract or catheter hub,
 41 3. contaminated infusate, or 4. bacteria from an existing
 42 infection in the bloodstream attaching to the catheter [19].
 43 BSIs have the potential to cause sepsis and occur when
 44 bacteria enter the bloodstream [20]. *Staphylococcus aureus*
 45 (*S. aureus*) is a lethal bacteria frequently found on skin
 46 that commonly causes BSIs [21], defined as a dysregulated
 47 host immune re-

1 sponse to infection that results in organ failure and
 2 a mortality rate of 20% [22]. Approximately 7.6% to
 3 35% of *S. aureus* BSIs are caused by PIVCs [23].

4 Even though PIVCs are frequently used, they are
 5 routinely not documented in clinical records [15].
 6 Moreover, sepsis is also poorly documented outside
 7 the intensive care units [24]. This lack of documentation
 8 makes it challenging to perform retrospective and real-time
 9 systematic quality surveillance of PIVC-related phlebitis
 10 or BSIs to identify learning opportunities for improving
 11 PIVC care to lower phlebitis, BSI-related and PIVC-related
 12 adverse event (AE) incidents. Hence, AE reports or documents,
 13 which are customarily used to report PIVC failures, were
 14 selected as the clinical text for this project. To capture
 15 documented observable patient states and infer underlying
 16 knowledge of PIVC-related phlebitis or BSI from clinical
 17 text, an ontology that models clinical knowledge representation
 18 and reasoning is necessary.

19 3.1. Relevant Ontology Resources

20 There lacks an ontology specifically for sepsis-related
 21 BSI, infection signs, anatomical locations, medical devices,
 22 and procedures. However, pre-existing ontologies can contain
 23 relevant concepts. The Infectious Disease Ontology (IDO)
 24 [25] has sepsis and hospital-acquired infection entities.
 25 Sign and symptom entities are present in the Ontology for
 26 General Medical Science (OGMS) [26] and vital sign entities
 27 exist in the Vital Sign Ontology (VSO) [27, 28]. Anatomical
 28 locations can be described using anatomical entities of the
 29 Foundational Model of Anatomy Ontology (FMA) [10, 29] and
 30 anatomical spatial location descriptor entities from the
 31 Biological Spatial Ontology (BSPO) [30]. Because AE reports
 32 are used, the adverse event entities in the Ontology of
 33 Adverse Events (OAE) [31, 32] might also be relevant.
 34 Furthermore, relationship object properties in the Open
 35 Biological and Biomedical Ontology (OBO) Relation Ontology
 36 [7, 33] could be used to link different entities together
 37 to capture more information.

38 In addition to ontologies, there are also potential
 39 relevant terminologies and taxonomies. For example, there
 40 are different procedure, medical device, and catheter terms
 41 in the National Cancer Institute Thesaurus (NCIT) [34, 35].
 42 Potential relevant standardized nursing practice language
 43 is found in the International Classification for Nursing
 44 Practice (ICNP) terminology [36], Nursing Interventions
 45 Classification (NIC) taxonomy [37], and NANDA International
 46 Nursing

Table 1
Overview of Relevant Resources for This Study

Type	Resource	Relevant Concepts or Terms
Ontology	Infectious Disease Ontology (IDO)	Sepsis and hospital-acquired infection entities
	Ontology for General Medical Science (OGMS)	Sign and symptom entities
	Vital Sign Ontology (VSO)	Vital sign entities
	Foundational Model of Anatomy Ontology (FMA)	Anatomical entities
	Biological Spatial Ontology (BSPO)	Anatomical spatial location descriptor entities
	Ontology of Adverse Events (OAE)	Adverse event entities
	Open Biological and Biomedical Ontology (OBO) Relation Ontology	Relationship object properties
Terminology	National Cancer Institute Thesaurus (NCIT) terminology	Procedure and medical device terms
	International Classification for Nursing Practice (ICNP) terminology	Terms
Taxonomy	Nursing Interventions Classification (NIC) taxonomy	Terms
	NANDA International Nursing Diagnoses Classification taxonomy	Terms
Clinical Guideline	1998 Visual Infusion Phlebitis Scale	Visual infusion phlebitis grading scale
	2021 Infusion Therapy Standards of Practice Updates	Updated infusion therapy practice standards

Diagnoses Classification taxonomy [38]. Furthermore, infusion phlebitis-related information can be obtained from the 1998 Visual Infusion Phlebitis Scale [39] and the 2021 Infusion Therapy Standards of Practice Updates [40]. Concepts or terms from these resources can be used to expand the ontology if deemed necessary by ontology users. The relevant ontologies, terminologies, taxonomies, and clinical guidelines can be found in Table 1.

4. Use Case Objective

The use case objective was to develop a model for representing and reasoning about PIVC-related BSIs in the unstructured free-text of AE reports, describe the development process, and discuss the discoveries and limitations. From the research question “is there a connection between BSIs and PIVCs at the hospital?”, competency question requirements for an ontology representing and reasoning about PIVC-related BSIs were identified by clinicians as follows:

1. Does patientA have phlebitis, and was it infectious, chemical, or mechanical phlebitis?
2. Does patientA have an infection?
3. Does patientA have a BSI?
4. How many patients have an infection or BSI?
5. Which patients have sepsis?
6. Does patientB have a catheter?
7. Does patientB have a PIVC?
8. How many catheters does patientB have, where are they, and why does patientB need them?

9. Does patientC have an infection and catheter? If so, was patientC’s infection associated with a catheter?

5. Materials

5.1. Annotated Dataset

Documents for annotation are from an AE synthetic dataset. The documents are based on unstructured free-text AE notes within the extracted AE reports from the electronic incident reporting system at St. Olavs hospital, Trondheim University Hospital in Trondheim, Norway between September 2015 to December 2019 [2]. The synthetic dataset contains 100 AE notes or documents which were manually created and verified by a nurse to ensure clinical data is anonymized (See Fig. 1(a)). The Norwegian Regional Committees for Medical and Health Research Ethics (REK) has granted ethical approval to use AEs in this paper (approval no 2018/1201/REKmidt, 26814).

As shown in Fig. 1(b), documents were annotated by 8 annotators with clinical backgrounds over 4 annotation sessions, such that each annotator annotates 10 documents in session 1 and 20 documents in the remaining 3 sessions (i.e., 70 documents annotated over 4 annotation session). In each annotation session, annotators followed the annotation guideline and used the Brat rapid annotation tool (BRAT) [41] to annotate the documents. Then, documents were evaluated and manually screened to identify ambiguities for revising the annotation guideline. The 8 annotators each anno-

tated 70 documents in 4 sessions, resulting in 560 annotated synthetic AE documents as shown in Fig. 1(b and c) (i.e., 8 annotators * 70 annotated documents * 4 sessions = 560 total annotated synthetic AE documents).

5.2. Annotation Guideline

An annotation guideline was developed based on the clinical research question: Is there a connection between BSIs and PIVCs at the hospital? Discussions with nurses provided insight into how catheters can be distinguished explicitly by the name or implicitly based on the anatomical insertion site or procedure mentioned. This formed into four domain-specific questions of interest:

1. What are the different signs of infections, specifically for BSIs, sepsis, or infected PIVCs?
2. What are the signs for different types of catheters?
3. Where are the anatomical insertion sites of catheters?
4. What procedures, interventions, and activities can be related to catheter use?

Answers to domain-specific questions were then sorted into following 7 main categories:

1. **Sign**: infection signs
2. **Location**: anatomical insertion sites
3. **Device**: signs of catheter types
4. **Procedure**: procedures, interventions, or activities related to catheters
5. **Sensitivity**: protected health information
6. **Person**: individuals mentioned, such as patient, clinician, or relative.
7. **Whole**: label representing the span of the whole text and given to indicate if the document contains information about infection, BSI, sepsis, faulty device malfunctioning, catheter, PIVC, or is sensitive.

All categories except **Whole** have a hierarchy with more specific subcategories to capture detailed granularity from text (e.g., in Fig. 2, the **Device** category has a **catheter** subcategory which contains more specific subcategories like **PIVC** subcategory). Furthermore, to capture relationships between categories for downstream analysis (e.g., infection sign at a specific location), the following four relationships to link categories were included:

1. **Person** $\xrightarrow{\text{Person has}}$ **Sign, Location, Device, or Procedure**

2. **Procedure** $\xrightarrow{\text{Procedure uses}}$ **Device**
3. **Sign** $\xrightarrow{\text{Caused by}}$ **Device or Procedure**
4. **Sign, Device, or Procedure** $\xrightarrow{\text{Located nearby/on/in}}$ **Location**

Using the seven categories and four relationships, a preliminary annotation guideline describing how each category and relationship was created. An example of the **Device** category in the annotation guideline is depicted in Fig. 2. The importance of having an annotation for consistent annotations and two possible annotation variations are shown in Fig. 3 as either without relationships and detailed granularity (Fig. 3(a)) or with relationships and detailed granularity by utilizing subcategories and attributes (Fig. 3(b)). Annotation guidelines from each of the 4 annotation sessions are available online³ [2].

6. Terminology Development for Annotations

In annotations, categories are known as entities for labeling a span of words or phrases. Whereas in ontologies and terminologies, categories are known as classes. To separate the annotation guideline from the terminology and ontology, the annotation categories and entities will be in **bold font**, and the terminology and ontology classes will be in typewriter font.

6.1. Design Decision for Annotations

The terminology was developed using the bottom-up approach based on the annotation guideline refinement process from 4 iterations. Competency questions were not used to create this terminology. This terminology is meant to assist annotators who want to label text and to allow users interested in performing downstream analyses the ability to adjust the granularity of labels. The objective is solely to represent the annotated corpus and provide structure to the terminology used by annotators. Thus, included individuals are based on concrete examples from the annotated corpus. A simplified example of how annotation labels in annotated documents are added to the terminology as individuals is provided in Fig. 4.

Instead of reusing and re-defining existing ontologies, it was easier and simpler to develop a terminology based on what is documented in the data. For instance, although the FMA does contain relevant anatomical

³<https://folk.ntnu.no/melissay/ae-guidelines/>

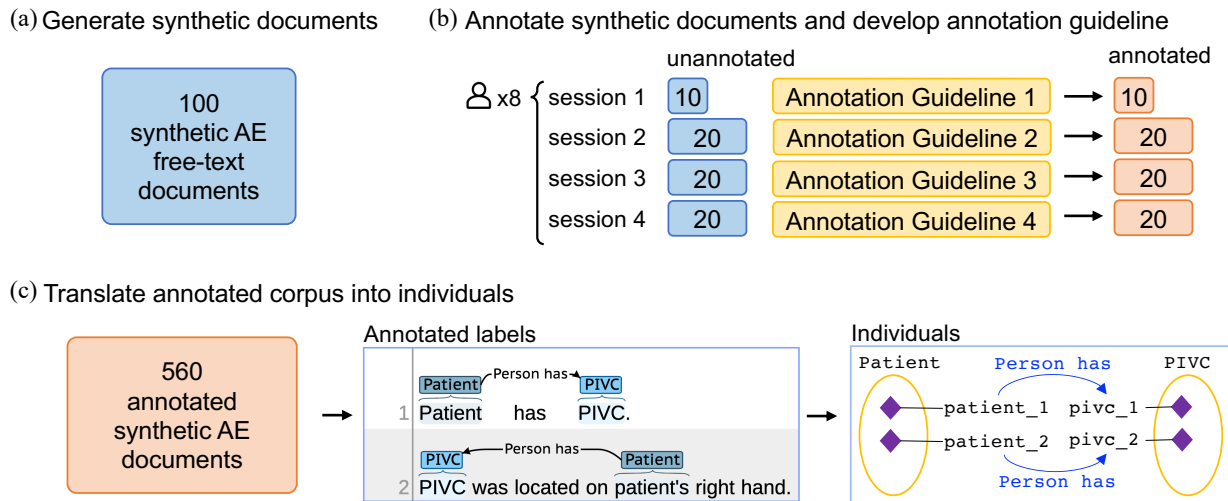


Fig. 1. From unannotated documents to an annotated corpus used to populate individuals in a terminology. (a) 100 synthetic adverse event (AE) unstructured free-text documents were manually generated. (b) Those synthetic documents were annotated by 8 annotators over 4 annotation sessions using revised annotation guidelines. Each annotator annotated 70 documents (i.e., 10 documents in session 1 and 20 documents in the remaining 3 sessions). (c) The 8 annotators each annotated 70 documents to produce a total of 560 annotated synthetic AE documents. Each document was translated into an individual and each label within a document was also translated into an individual. In the simplified example, an annotated document has 2 **patient** labels, 2 **PIVC** labels, and 2 $\xrightarrow{\text{Person has}}$ relationships linking the labels. Each label is converted into an individual (i.e., a purple diamond) of the corresponding class (i.e., **Patient** or **PIVC** yellow circle). Then the labels are linked using the $\xrightarrow{\text{Person has}}$ object property, similarly to how the $\xrightarrow{\text{Person has}}$ relationship links labels in the annotated text.

Table 2
Convert Annotation Guideline to Terminology

Annotation Guideline	Terminology
Entity (category) hierarchy	Class hierarchy
Attributes which provide detailed entity information	Data properties
Relationships between entities	Object properties

parts, the ontology was too complex and detailed to be incorporated easily into the terminology to fit the use case's purpose. Additionally, the purpose was to include concrete items that are documented in the terminology and not provide terminology for all existing items. By opting to simplify the terminology, it was easier to build the terminology directly based on the annotation guideline and modify the terminology to incorporate feedback from discussions with clinicians.

6.2. Convert Annotation Guideline To Terminology

The categories, attributes, and relationships in annotation guidelines described in Section 5.2 correspond to classes, data properties, and object properties in terminologies (Table 2 and Fig. 4).

The terminology was developed from the annotation guideline by translating each hierarchy of entities into a class hierarchy, using attribute information to add data properties, and converting relationships into object properties. During development, the terminology was modified to remove ambiguities by adding new class hierarchies and modifying class names, object properties, and data properties. Specifically, to remove ambiguity between symptoms, infection signs, and device malfunction signs, the **Observation** class was introduced to encompass them. Additionally, the **Sensitive** category was revised to **Identifier** class and the $\xrightarrow{\text{Caused by}}$ relationship was revised to the $\xrightarrow{\text{Is observed with}}$ relationship. A summary of converted 7 main classes can be found in Table 3.

The results from all 4 annotation sessions were included as individuals in the terminology, but the terminology only reflects results based on the last annotation guideline. To accommodate revisions in the annotation guideline, annotation categories that were revised in the guideline are updated in the terminology correspondingly. For instance, removed annotation categories are reflected by changing the granularity of the removed category to a higher level. Annotation categories can also be re-organized to become subclasses

Table 3

Annotation Guideline vs Annotated Adverse Event NOte Terminology (AAENOTE). Annotation categories and entities are in **bold font** and the terminology and ontology classes are in `typewriter font`

Annotation Categories	Category Description	Sub-categories	Terminology Classes	Class Description	Subclasses
Sign	Infection signs	29	Observation	Documented clinical observation including symptoms, infection signs, and device malfunctions	41
Location	Anatomical insertion sites	17	Anatomical Location	Anatomical location	25
Device	Signs of catheter types	16	Medical Device	Treatment equipment or part	19
Procedure	Procedures, interventions, or activities related to catheters	31	Procedure	Procedure, intervention, or activity for catheter-related versus non-catheter related	36
Sensitivity	Protected health information	14	Identifier	Protected health information	14
Person	Individuals	3	Person	Individual	3
Whole	Label representing whole text indicating the note contains infection, BSI, sepsis, faulty device malfunctioning, catheter, PIVC, or sensitive information	0	Annotated Document	Representation of an AE note's filename, annotation session, annotator, and annotated labels	4

of a different class. Moreover, newly added annotation categories are directly added as new classes in the terminology. An example is depicted in Fig. 5.

Although the terminology was not developed to answer competency questions, the competency questions were still used to determine what could be found in annotated documents. To answer competency questions, the annotated documents were imported into the terminology as individuals.

7. Terminology Results for Annotations

7.1. Annotated Adverse Event NOte Terminology (AAENOTE)

Annotated AE documents and their annotations are modeled by the Annotated Adverse Event NOte Terminology (AAENOTE). To increase accessibility, the terminology is in both English and Norwegian. There are 149 classes, 5 object properties, 27 data properties, and 4470 individuals. The 7 classes which form the main hierarchies are:

1. **Observation**: Any sign or symptom that can be monitored.
2. **Anatomical Location**: Any anatomical body part, organ, or relative position of the body.
3. **Medical Device**: Any instrument, device, or equipment used for a medical purpose.
4. **Procedure**: Any procedure, intervention, or activity related to catheters.

5. **Identifier**: Protected health information that can be used to identify an individual.
6. **Person**: An individual, such as patient, clinician, or relative.
7. **Annotated Document**: Annotated adverse event document metadata and labels.

Relationships between the 7 class hierarchies can be formed using the following 5 object properties:

1. **Person** $\xrightarrow{\text{Person has}}$ **Observation, Anatomical Location, Medical Device, or Procedure**
2. **Procedure** $\xrightarrow{\text{Procedure uses}}$ **Medical Device**
3. **Observation** $\xrightarrow{\text{Is observed with}}$ **Medical Device or Procedure**
4. **Observation, Medical Device, or Procedure** $\xrightarrow{\text{Located nearby/on/at/in}}$ **Anatomical Location**
5. **Annotated Document** $\xrightarrow{\text{Has label}}$ **Anatomical Location, Identifier, Medical Device, Observation, Person, or Procedure**

Each annotated AE note or document is an individual of the **Annotated Document** class, can have object properties linking the AE document to individual labels from the other 6 class hierarchies, and has data properties for the filename, annotation session, and annotator. The individuals of the other 6 hierarchies can also have object properties and data properties if an annotator provides that information.

Device Category (Enhet)

Different catheters and parts of catheters must be identified so that machine learning classifiers can distinguish peripheral intravenous catheters (PIVKs) from other catheters. Names and parts of catheter are provided here:

(a)

- Catheter (Kateter)
 - Venous catheter (Venekateter)
 - Central venous catheter (Sentralt venekateter)
 - Hemodialysis catheter (Hemodialysekateter)
 - Midline (Midline)
 - PICC (PICC)
 - Hickman (Hickman)
 - VAS (VAS)
 - Peripheral intravenous catheter (PIVC) (Perifert venekateter (PIVK))
 - Arterial catheter (Arteriekateter)
 - Urinary catheter (Blærekateter)
 - Epidural (Epidural)
- Device Parts (Enhetsdeler)
 - Pump (Pumpe)
 - Tubes (Rør)
 - Valves (Ventiler)

Given the following example:

1 English: At 4:30 found the patient lying on the floor with discontinued urinary catheter and pivcs.
 2 norsk: kl 04.30 fant pasienten liggende på gulvet med seponert blærekateter og pvker.

The result should be:

1 English: At 4:30 found the patient lying on the floor with discontinued urinary catheter and pivcs.
 2 norsk: kl 04.30 fant pasienten liggende på gulvet med seponert blærekateter og pvker.

Device Annotation Rules

1. Annotate catheters and other devices from the list.
2. If the abnormal sign was caused by a device not listed, then annotate it as the highest category "Device (Enhet)". Be sure to identify the device and draw a "Caused by (Forårsaket av)" relationship to link the sign to device.

Fig. 2. In the annotation guideline, the **Device** category contains (a) a hierarchy of subcategories, (b) annotation examples, and (c) rules. Red font indicates revisions made to the guideline after a revision. Each category in the annotation guideline has a section similar to the **Device** category. Figure adapted from [1] with permission. ©2021 by the IEEE.

7.2. AAENOTE Evaluation

The purpose of AAENOTE is to model and provide semantic meaning to annotated AE notes or documents. The terminology was not developed based on competency questions, but it would be interesting to see what competency questions could be answered. Hence, AAENOTE was evaluated using the competency questions as requirements. Competency questions using AAENOTE can only be answered based on explicitly annotated classes or subclasses. Words or phrases that lack annotation are excluded from this terminology. Thus, only the annotation category labels provided by annotators are included in the individuals as classes.

Knowledge represented by the terminology can either be found explicitly, based on the direct classes and relationships, or be inferred implicitly, based on underlying concrete knowledge and indirect classes and

relationships. For example, the competency question “Does patientA have an infection?” can be answered explicitly by finding an individual of the patient class who has an infection (i.e., Patient $\xrightarrow{\text{Person has}}$ infection). It can also be answered implicitly by finding an anatomical location that has an infection (i.e., Infection $\xrightarrow{\text{Located nearby/on/at/in}}$ anatomical location) because an anatomical location, in this terminology, must be part of a person. However, if infection is not explicitly mentioned, this terminology cannot implicitly determine what other observations combined indicate an infection.

SPARQL query results vary depending on the clinician’s interest in knowing how many instances a patient has for one class or a combination of that one class with other classes. For example, to find how many patients explicitly have an infection, the query can be written to find all instances where either individuals of the patient class have the object property “person has” to an individual of the infection class (i.e., Patient $\xrightarrow{\text{Person has}}$ infection) or the individuals of the patient class have the object property “person has” to an individual of the infection class and/or an individual of the observation class or its subclass (i.e., Patient $\xrightarrow{\text{Person has}}$ infection and other observation(s)). The different number of instances is shown in Table 4; the first query has 14 instances where a patient has an infection regardless of other observations and the second query divides the 14 instances into Query Result 2-14 to show the number of instances where a patient has an infection with different combinations of other observations. To implicitly find patients that have an infection, the infection must be located at an anatomical location of a person. Queries about infections at an anatomical location can be written using Infection $\xrightarrow{\text{Located nearby/on/at/in}}$ anatomical location) or using Infection and other observation(s) $\xrightarrow{\text{Located nearby/on/at/in}}$ anatomical location if the clinician is curious about additional observations that were documented with the infection. In AAENOTE, there is only 1 instance where an anatomical location (i.e., skin) has infection, as shown in Query Result 1 of Table 5. However, for clinicians, it is more informative to look at additional potential observations that can indicate infection around a certain location; Table 5 Query Results 2-10 provide some other observations that were found located with skin. The clinical knowledge required to find indications of infections and catheters is lacking in AAENOTE.

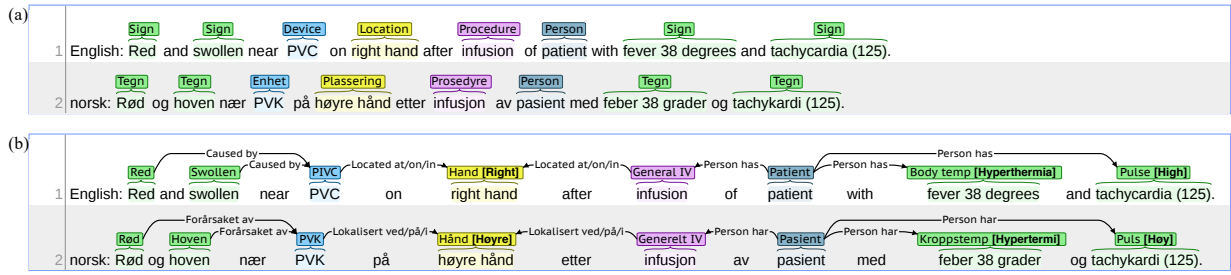


Fig. 3. Annotation granularity differences in English and Norwegian. (a) Using the Brat rapid annotation tool, it is possible to annotate text using only the categories (i.e., **Sign, Location, Device, Procedure, Person**). (b) However, text can be annotated with more detail to ensure information is not lost downstream by using relationships, subcategories, and attributes. For instance, relationships are used to link one label to another (e.g., “Red” is linked to “PIVC” using the *Caused by* relationship). Additionally, “right hand” which was previously labeled **Location** in (a) is now labeled using **Location**’s subcategory “Hand” and given the attribute [Right]. Reprinted from [1] with permission. ©2021 by the IEEE.

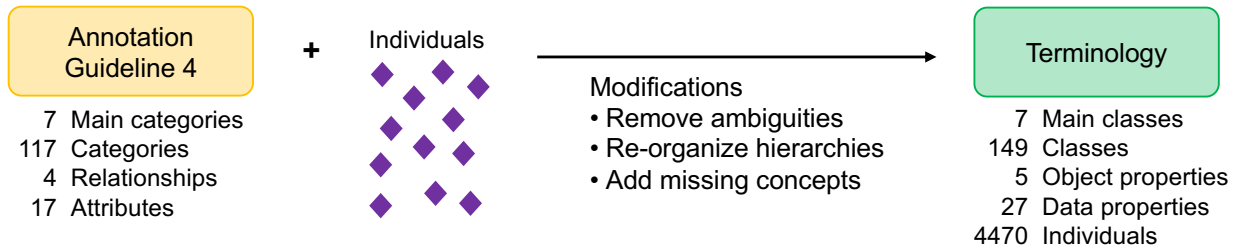


Fig. 4. Terminology development. The annotation guideline from the fourth annotation session was converted into a terminology. Annotation categories were converted into ontology classes, relationships into object properties, and attributes into data properties. Then the individuals of documents and labels were added. Additional modifications were incorporated as needed, such as removing ambiguities, re-organizing hierarchies, and adding missing concepts. This resulted in the AAENOTE which models and provides an index of annotated documents.

Explicit queries and basic implicit queries in AAENOTE can answer 7 of the 9 competency questions. However, these queries still lack the clinical knowledge needed to include more implicit queries by combining additional observations, anatomical locations, and/or procedures to identify indications. In Appendix A, Table 6 provides the terminology classes and relationships used to form explicit and implicit queries to explicitly and implicitly answer each competency question. Additionally, concrete underlying knowledge used to make inferences are also provided. Results can be found in Appendix A.

8. Ontology Development for Domain Knowledge

8.1. Design Decision for Domain Knowledge

In this use case, the clinicians’ need is to focus on identifying and inferring a patient’s state based on documented observations in AE documents that are related

to PIVCs and BSIs. A patient’s underlying state can be measured by monitoring devices that measure vital signs (e.g., blood pressure, pulse, and respiratory rate) or exhibited by observable signs and symptoms (e.g., pain, fever, chills, and mobility impairment). Those measurable and observable signs and symptoms are then documented by clinicians in the electronic health record (EHR) to record patient conditions and communicate with other clinicians. When an AE incident could have or has happened, clinicians will go through the documentation to recall what occurred and report it in a separate AE document.

To limit the scope of modeling the clinical knowledge ontology, 15 documents were used as examples to form the classes and individuals. Each document was split into sentences to identify catheter and infection indications at the sentence-level and document-level. At the sentence-level, individual sentences were presented to clinicians who determined what observations, anatomical locations, or procedures within the text are needed to determine catheter and infection in-

Table 4
AAENOTE SPARQL Query Result: Patient has Infection

Query Result	Instances	# Observations	Person		Observation												
			patient		blood pressure	body temp	c reactive protein	consciousness level	infection	neurological and physiological	observation	pulse	red	respiratory rate	sepsis	swollen	
1	14	1	✓						✓								
2	1	1	✓						✓								
3	1	2	✓					✓	✓								
4	1	2	✓						✓				✓				
5	1	2	✓						✓					✓			
6	1	3	✓			✓	✓		✓								
7	1	3	✓			✓			✓					✓			
8	1	3	✓					✓	✓	✓							
9	1	3	✓					✓	✓		✓						
10	2	3	✓						✓				✓				✓
11	1	4	✓					✓	✓	✓		✓					
12	1	5	✓			✓	✓	✓	✓				✓				
13	1	6	✓			✓	✓	✓	✓				✓			✓	
14	1	8	✓			✓	✓	✓	✓	✓	✓		✓				

Query result 1: Patient $\xrightarrow{\text{Person has}}$ infection.

Query result 2-14: Patient $\xrightarrow{\text{Person has}}$ infection and other observation(s).

dication. Only clinician identified sentences with indications were included as individuals in the ontology. At the document-level, individual sentences from a document were presented together, allowing clinicians to identify indications based on additional information from a more complete documented story. Presenting the document as separate sentences allows clinicians to identify concepts within a limited example to determine what can and cannot be determined based on limited information. Whereas, allowing a clinician to see the whole document presented more possibilities and helped identify necessary data combinations for indications of catheters and infections.

Because the focus of the ontology includes catheter indications and the clinicians have identified that it is important to identify infusion phlebitis, infusion phlebitis was included in the ontology as rules based on the 1998 Visual Infusion Phlebitis Scale [39] included in the 2021 Infusion Therapy Standards of Practice Updates [40]. Furthermore, causality is not within the scope because the exact reason for chemical and mechanical reactions resulting in infection-like signs are more likely found at the body's cellular or

genetic-level in pathophysiology studies [42, 43] and unlikely to be documented in AE documents.

Anatomical locations in this ontology were kept simple and similar to the AAENOTE. Clinical guidelines for catheter insertion into anatomical locations are very specific (i.e., a central venous catheter is inserted in the jugular vein until it reaches the superior vena cava [44]) because clinical guidelines provide instructions on how to perform a task properly. However, clinical documentation is more general (i.e., central venous catheter in the chest) because this is common clinical knowledge and the documentation is written for other clinicians to understand. To match the ontology with available documented data, this ontology relies on general anatomical location terminology. If clinicians deem it necessary, clinical guidelines can be included in a separate ontology focused on identifying catheter locations based on clinical guidelines and the FMA. Inclusion of clinical guidelines to identify specific catheter insertion sites and placement requires anatomical knowledge. For instance, to identify a central venous catheter's general anatomical location using a clinical guideline and the anatomy ontology FMA, the ontology would need to:

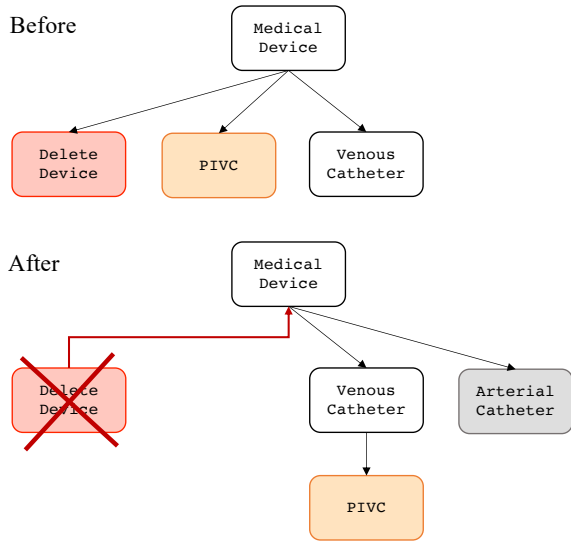


Fig. 5. Handling annotation guideline revisions in the terminology. If the **Delete Device** annotation category in red is removed from the annotation guideline, then the **Delete Device** class is removed from the terminology and all individuals of the **Delete Device** terminology class are now part of the superclass **Medical Device**. If the **PIVC** (peripheral intravenous catheter) annotation category in orange is re-organized to become the sub-category of **Venous Catheter**, then the **PIVC** class is now a subclass of **Venous Catheter** and the individuals remain as part of the **PIVC** class. If the **Arterial Catheter** annotation category in gray is added, then the **Arterial Catheter** class is added to the terminology and the corresponding individuals will be added as well.

1. Identify the jugular vein insertion site and the superior vena cava placement.
2. Infer that the jugular vein is in the neck and the superior vena cava is present within the superior and middle mediastinum [45], annotated as anatomical location chest.
3. Convert the terms into more general terms that match the available data (i.e., vena cava is in the chest).

8.2. Representing Domain Knowledge

Discussions with clinicians about example documents and indications formulated the classes, object properties, data properties, and rules within the ontology. The provided indications were sorted and summarized to match the ontology closely. Afterward, indications were verified by clinicians and included in the ontology using SPARQL queries. A list of indications can be found in Appendix B.2.1 to Appendix B.2.7.

Table 5
AAENOTE SPARQL Results for Observations Located at the Skin

Query Result	Observations						
	Instances	edema	infection	pain	red	swollen	warm
1	1		✓				
2	3			✓			
3	3					✓	
4	2			✓		✓	
5	2			✓	✓	✓	
6	2				✓		
7	2				✓	✓	
8	1						✓
9	1				✓		✓
10	1	✓			✓	✓	

Query result 1: Infection
 Located nearby/on/at/in → anatomical location.
 Query result 2-10: Observation
 Located nearby/on/at/in → skin.

9. Ontology Results for Domain Knowledge

9.1. Catheter Infection Indications Ontology (CIIO)

The Catheter Infection Indications Ontology (CIIO) represents clinical knowledge for signs of infections and catheters to identify PIVC-related BSIs and was developed to accompany the AAENOTE. Similar to AAENOTE, this ontology is also in both English and Norwegian. There are 57 classes, 10 object properties, 16 data properties, and 187 individuals. The 7 classes which form the main hierarchies are:

1. **Observation**: Any sign or symptom that can be monitored.
2. **Anatomical Location**: Any anatomical body part, organ, or relative position of the body.
3. **Medical Device**: Any instrument, device, or equipment used for a medical purpose.
4. **Procedure**: Any procedure, intervention, or activity related to catheters.
5. **Person**: An individual.
6. **Document**: Unstructured free-text report consisting of sentences documented to represent observable patient states.
7. **Sentence**: A set of words documented to represent observable patient states.

Relationships between the 7 class hierarchies can be formed using the following 10 object properties:

1. Person's subclass Patient $\xrightarrow{\text{Patient has}}$ Observation, Anatomical Location, Medical Device, or Procedure.
2. Procedure $\xrightarrow{\text{Procedure uses}}$ Medical Device.
3. Observation $\xrightarrow{\text{Is observed with}}$ Medical Device or Procedure.
4. Observation, Medical Device, or Procedure $\xrightarrow{\text{Located nearby/on/at/in}}$ Anatomical Location.
5. Document or Sentence $\xrightarrow{\text{Contains}}$ Observation, Anatomical Location, Medical Device, Procedure, or Person. Additionally, only Document $\xrightarrow{\text{Contains}}$ Sentence.
6. Procedure's subclass General IV $\xrightarrow{\text{Is combined with}}$ a different General IV
7. Procedure's subclass General IV $\xrightarrow{\text{Is IV for}}$ Procedure's subclass Infusion.
8. Procedure's subclass General IV $\xrightarrow{\text{Medication should have been}}$ a different General IV.
9. Observation, Anatomical Location, Medical Device, Procedure, or Person $\xrightarrow{\text{Is documented in}}$ Document or Sentence. Additionally, only Sentence $\xrightarrow{\text{Is documented in}}$ Document.
10. Anatomical Location $\xrightarrow{\text{Location has}}$ Observation, Medical Device, or Procedure.

Each example of a sentence documented in the report is an individual of the Sentence class. Sentence class individuals contain Observation, Anatomical Location, Medical Device, Procedure, or Person individuals that are present within text. An individual of the Document class contains the Sentence individuals that form it and the content from those sentences. Similarly to AAENOTE, individuals of Observation, Anatomical Location, Medical Device, Procedure, and Person can also have object properties and data properties.

9.2. CIO Evaluation

Designed to capture and reason about clinical catheter-related and infection-related signs and symptoms doc-

umented in an AE report, the CIO provides the missing clinical domain knowledge for the AAENOTE. CIO can answer 8 of the 9 competency questions based on assumptions and indications. The assumptions are that 1 AE document represents 1 patient and all sentences within a document are likely to describe concepts within the same event (Appendix B.1). Indications for catheters and infections are provided in (Appendix B.2). Additionally, the ontology classes and relationships used to answer each competency question is detailed in Table 26.

10. Discussion

10.1. AAENOTE Scope and Limitations

The clinician asks questions about the condition of a physical patient and the patient's PIVCs, but AAENOTE is about words in the AE document regarding a patient event. The correspondence between clinical condition and document content is represented by CIO. So the answer to a question about a patient's condition will be answered from the document annotation and text. Understanding a query means translating it from clinical concepts to document content concepts. Here, the terminology is used to fit and answer questions. SPARQL queries can answer most competency questions, and the results can be used as consistency checks. SPARQL can be used to count and make quantitative queries about the number of catheters and devices. Likewise, qualitative results enabled clinicians to verify if results matched their expectations of clinical events (i.e., the anatomical location of specific catheters) or why the AE was reported (i.e., incorrect medical devices used in a particular procedure).

There are several limitations to the AAENOTE. Although this terminology does not cover sepsis, it does cover events that could lead to sepsis. This terminology lacks the clinical knowledge required to answer several competency questions more in depth. Moreover, it is not always possible to find out what a patient has because of the note's content or provided annotations. Most documents do not explicitly mention a patient because these are AE documents, and it is often implied that the adverse event has happened to a patient. Annotators will often not link the patient to all possible observations, anatomical locations, medical devices, or procedures because typically, one AE document refers to one event or patient. Furthermore, referent tracking and resolution are not handled by AAENOTE. Thus,

multiple mentions of a label or individual do not indicate whether it is the same item or a different item. For example, given the annotated document in Fig. 1(c), the terminology cannot determine if the 2 `patient` individuals refer to the same patient or not because each label is an individual. Similarly, the same also applies to the 2 `pivc` individuals. In this example, a query counting how many patients have a PIVC will answer 2. However, based on the context, both sentences in the document likely refer to the same patient and PIVC.

10.2. CIIO Scope and Limitations

The CIIO is an abstract ontology with instances populated using the terminology. Only parts of the AAENOTE necessary for creating queries with clinician provided indications were included or extended. This provides flexibility, allows for easier maintenance of the ontology, and separates the needs of clinicians who use CIIO and annotators who use AAENOTE.

Based on assumptions and indications, competency questions can be answered using SPARQL queries. The queries retrieve documents and translate the content for the user by identifying concepts necessary to answer the competency questions. Thus, the retrieved documents and concepts can provide sufficient information for clinicians to further decipher retrieved answers. For example, the exact reason why a patient needs a catheter cannot be determined by the query unless there is a direct relationship (i.e., `procedure` Procedure uses \rightarrow `medical device`) because the list of indications do not provide reasons for catheter usage. However, the clinician can view the retrieved list of medical devices and procedures within a document to determine why the medical devices were required.

The lack of detailed documentation inhibits the query's ability to answer certain questions. This includes why a patient needs a catheter as previously stated, counting catheters within a patient, and where the catheters are located in a patient. Counting the exact number of catheters per document is not possible because multiple sentences within a document could be describing the same catheter or multiple procedures could use the same catheter. The exact anatomical location of catheters per document cannot be determined for several reasons. Multiple sentences within a document could be describing the same catheter at the same location but with more general terms (i.e., `arm` instead of `hand`). The location's position not being documented makes it difficult to distinguish if a body part is

on the same side. Various procedures can be performed at the same location. For example, given an example document, "The patient received IV fluids in elbowA and IV antibiotics in right handB. Right armC showed signs of phlebitis." Here, `handB` is part of `armC` because both are on the right side, but `elbowA` might or might not be part of `armC`. Additionally, `armC` is likely a more general term for `handB`. Furthermore, an additional anatomical ontology is needed to infer the possible locations based on catheter type.

10.3. Purpose of Separate Terminology and Ontology

The terminology and ontology were developed for different purposes using different methods. AAENOTE is intended to be useful for annotators who are annotating documentation and a way to provide them a structured terminology with varying granularity. In comparison, CIIO is intended to be used by clinicians to clinically reason about a patient state. The design process of AAENOTE is heavily based on the explicit terms used in annotations and not on competency questions. It uses the bottom-up method and the annotation guideline development process to capture semantic annotations. In contrast, the design process of CIIO is based on the competency questions, which focus on patient states. Designed with a top-down method, it is based on concepts naturally used by clinicians to describe patients. Mixing the indexed annotation terminology with a clinical knowledge ontology would increase the complexity of reusing and maintaining the ontology over time. Thus, the terminology and ontology have different functionalities and are kept separately.

Separating the terminology from the ontology enables annotators to annotate concepts with standard terms and clinicians to reason about the annotated concepts. Here, the ontology does not impact the terminology annotators can use. Instead, the ontology provides knowledge for the terminology. Thus, our methods avoid a large amount of time, effort, and manual curation previously required to map terms to an ontology [9]. Instead, our ontology utilizes concepts in the terminology and is limited by the competency questions, clinical guidelines used, and clinician provided rules.

10.4. Representing Annotated Data and Revisions

Annotating data provides data meaning, and the corresponding annotation guideline and terminology provide additional structured semantic meaning. Ad-

ditionally, the terminology can represent knowledge and disambiguate annotation entities and relationships. Each annotation session uses a slightly different annotation guideline that has been revised based on the previous annotation session. Hence, revisions in the annotation guidelines include added, re-organized, and removed categories. Since results from 4 different annotation sessions are included as individuals in the AAENOTE, this indicates the terminology can handle different versions of annotated data while preserving semantic meaning. It is also possible to easily customize the granularity (i.e., superclasses, classes, or subclasses) and extend and retract the terminology as needed based on clinician needs without breaking the terminology.

To alleviate the problem with overlapping terms and ambiguities experienced by [8] and remove mismatches between the annotations and the terminology experienced by [9], all annotators in our study could only use provided annotation labels in the terminology. By using concrete concepts from the annotation guideline based on what can be found in the documentation instead of using other pre-existing ontologies, it lowers the complexity and simplifies the terminology.

10.5. Representing Annotated Documents The Way Clinicians View Patients

The AAENOTE is a terminology that provides an index of what is annotated in a clinical document. It is not used to design a language's syntax, grammar, or terms because AAENOTE is a terminology for understanding the language and underlying meanings. Instead, it is the interpreted formalized language that has been translated into basic statements for reasoning. To capture relevant information, the underlying document was represented by annotated labels and relationships for the task of question answering and text understanding instead of solely retrieving information. Hence, the terminology focuses only on items of interest and is blind to items not within the terminology.

The corresponding CIO is an ontology that models clinical knowledge missing from AAENOTE. It provides the missing clinical knowledge required to reason about the presence of catheters and infections documented in clinical text. Although the data modeled is documented text, it enables clinicians to think about the data as an individual patient because they already do this routinely when documenting patient states.

10.6. Understandability and Accessibility for Domain Experts

For domain experts without formal ontology training, the approach taken makes ontology development understandable and accessible. The employed approach made it possible for clinicians to understand and be part of the design process. In practice, the approach was a necessity to progress in developing the ontology to incorporate clinical knowledge.

10.7. Clinical Utility

The collected competency questions and requirements are largely met. Thus, we have reached our main objective of developing a terminology and ontology that can be used by clinicians and hospital systems to get a systematic overview of identifying and reasoning about PIVC-related phlebitis and sepsis in an AE corpus. Furthermore, our ontology is a step towards automated and continuous quality control that move beyond today's focus on repeated point prevalence quality controls, like the Peripheral Intravenous Catheter mini Questionnaire (*PIVC-miniQ*) [46].

11. Future Work

For the sepsis-related use case, the synthetic AE dataset used for annotations is a placeholder for the real Norwegian AE dataset and clinical records from the EHR. Future work includes utilizing the current AAENOTE to annotate the real Norwegian AE dataset and clinical records. And to evaluate if clinical knowledge from the CIO can still be applied and expanded on new data. Additionally, the ontologies could be applied to AE documents at other Norwegian hospitals to assess how similar documentation and knowledge are between different hospitals. The ontologies can be directly translated to other Scandinavian languages (i.e., Swedish and Danish) and applied similarly at other Scandinavian hospitals. The design and representations are largely language-independent and should be easy to transform for eg. English clinical text about adverse events. After all, international literature suggests that the phenomena related to PIVC and devices are language-independent [15]. It would also be possible to provide multi-language querying over multi-language AE documents to enable cross-language repositories [47]. Furthermore, supervised machine learning methods can be employed to iden-

1 tify PIVC-related BSIs and classify patients requiring
2 additional monitoring.

3 4 5 **12. Conclusion**

6
7 The development process resulted in a terminology
8 and an ontology, specifically, the Annotated Adverse
9 Event NOTE Terminology (AAENOTE) which mod-
10 els annotated classes in annotated documents and the
11 Catheter Infection Indications Ontology (CIIO) which
12 models clinical knowledge for catheter and infection
13 indications. Although there is a clinical focus here, the
14 methodology for creating a terminology from an an-
15 notation guideline for semantically annotated data and
16 a domain knowledge ontology to represent knowledge
17 can be utilized in other domains to provide additional
18 semantic meaning to annotated datasets in other do-
19 mains.

20 21 22 **13. Data Availability**

23
24 The AAENOTE, CIIO, and SPARQL queries for
25 this paper are in the GitHub repository branch “swj” of
26 https://github.com/melissayan/aaenote_and_ciio. De-
27 tailed specifications for AAENOTE and CIIO were
28 generated using WIZARD for DOCUMENTING ONTOLOGIES
29 (WIDOCO) [48] and are available in English and
30 Norwegian at [https://folk.ntnu.no/melissay/ontology/](https://folk.ntnu.no/melissay/ontology/index.html)
31 [index.html](https://folk.ntnu.no/melissay/ontology/index.html).

32 33 34 **Acknowledgements**

35
36 The authors would like to acknowledge the eight
37 annotators for producing the annotated clinical ad-
38 verse event (AE) corpus. Funding was provided by the
39 Computational Sepsis Mining and Modelling project
40 through the Norwegian University of Science and
41 Technology (NTNU) Health Strategic Area. Addition-
42 ally, ethical approval was granted by the Regional
43 Committees for Medical and Health Research Ethics
44 (REK), approval no. 26814.

Appendix A. Annotated Adverse Event NOTE Terminology (AAENOTE) Competency Questions (CQs), SPARQL Queries, and Results

A.1. Details About Converting Annotation Guideline to Terminology

To further differentiate observations, Descriptive sign or symptom, Vital sign, Neurological and physiological, Wound, Lab result, and Device observation subclasses were introduced. In addition, Insertion site was introduced because some documents document a catheter's insertion site without mentioning a specific body part. Similarly, Organ parts, such as Skin and Circulatory system, were also introduced because they are documented instead of body part. For Medical Device, additional catheters were included (i.e., Intraosseous cannula and subcutaneous catheter for specificity. The category for device parts was removed because the terminology only covers catheter and catheter parts; thus, it is a part of a medical device if it is not under a catheter. For Procedure, Administration way was introduced to describe how a substance was administered into the patient, Catheter procedure subclasses all include "catheter" to indicate the action is for catheters only, and different Infusion types were included to differentiate from Injection types.

A hierarchy for certain data properties was introduced to organize the anatomical location descriptors, contents within a document, and document identity. For instance, document identity-related data properties were included for identification, such as annotator ID, filename, and annotation session. Unlike the data property values for body temperature (i.e., hyperthermia, normal, and hypothermia) and severity level (i.e., high, normal, and low), Consciousness level required a separate data property with values of alert, confusion, painfully responsive, unresponsive, and verbally responsive). The "observation is diagnosed by" and "observation said by" data properties were added to distinguish signs from symptoms because signs are what a clinician observes and symptoms are what a patient says.

A.2. AAENOTE Competency Questions and Terminology Usage

Table 6: AAENOTE Competency Questions and Terminology Usage

Competency Question	Terminology Classes and Relationships to Find Instances*
1. Does patientA have phlebitis, and was it infectious phlebitis, chemical phlebitis, or mechanical phlebitis?	<p>Explicit:</p> <p>Patient $\xrightarrow{\text{Person has}}$ phlebitis.</p> <p>Implicit:</p> <p>Phlebitis $\xrightarrow{\text{Located nearby/on/at/in}}$ anatomical location.</p> <p>[†]Anatomical location is part of a person, and typically a patient given the context is an AE note.</p> <p>[‡]Need clinical knowledge to determine if the phlebitis is infectious phlebitis, chemical phlebitis, or mechanical phlebitis.</p>

1	2. Does patientA have an infection?	Explicit:	1
2		Patient $\xrightarrow{\text{Person has}}$ infection.	2
3		Patient $\xrightarrow{\text{Person has}}$ infection and other observation (s).	3
4		Implicit:	4
5		Infection $\xrightarrow{\text{Located nearby/on/at/in}}$ anatomical location.	5
6		Infection and other observation (s) $\xrightarrow{\text{Located nearby/on/at/in}}$	6
7		anatomical location.	7
8		†Anatomical location is part of a person, and typically a pa-	8
9		tient given the context is an AE note.	9
10		‡Need clinical knowledge to determine if the observations	10
11		combined indicate infection without infection explicitly in-	11
12		cluded.	12
13	3. Does patientA have a BSI?	§ Cannot determine if there is a BSI without a microbiology laboratory	13
14		result of a positive blood culture and the cultured bacteria name.	14
15	4. How many patients have an infection or BSI?	Same as Competency Question 1 and 2.	15
16			16
17	5. Which patients have sepsis?	Explicit:	17
18		Patient $\xrightarrow{\text{Person has}}$ sepsis.	18
19		Patient $\xrightarrow{\text{Person has}}$ sepsis and other observation (s).	19
20		Implicit:	20
21		‡Need clinical knowledge to determine if the observations	21
22		combined indicate sepsis.	22
23			23
24	6. Does patientB have a catheter?	Explicit:	24
25		Patient $\xrightarrow{\text{Person has}}$ catheter.	25
26		Implicit:	26
27		Catheter $\xrightarrow{\text{Located nearby/on/at/in}}$ anatomical location.	27
28		†Anatomical location is part of a person, and typically a pa-	28
29		tient given the context is an AE note.	29
30		‡Need clinical knowledge to determine if the observations,	30
31		anatomical locations, and/or procedures combined in-	31
32		dicate a catheter is present.	32
33			33
34	7. Does patientB have a PIVC?	Explicit:	34
35		Patient $\xrightarrow{\text{Person has}}$ PIVC.	35
36		Implicit:	36
37		PIVC $\xrightarrow{\text{Located nearby/on/at/in}}$ anatomical location.	37
38		†Anatomical location is part of a person, and typically a pa-	38
39		tient given the context is an AE note.	39
40		‡Need clinical knowledge to determine if the observations,	40
41		anatomical locations, and/or procedures combined in-	41
42		dicate a PIVC is present.	42
43			43
44	8a. How many catheters does patientB have?	Same as Competency Question 5.	44
45			45
46			46
47			47
48			48
49			49
50			50
51			51

1 8b. Where are the catheters in patientB?

Explicit:

Patient $\xrightarrow{\text{Person has}}$ anatomical location (X).

Patient $\xrightarrow{\text{Person has}}$ Catheter (Y).

Catheter (Y) $\xrightarrow{\text{Located nearby/on/at/in}}$ anatomical location (X).

Implicit:

Catheter $\xrightarrow{\text{Located nearby/on/at/in}}$ anatomical location.

†Anatomical location is part of a person, and typically a patient given the context is an AE note.

10 8c. Why does patientB need the catheter(s)?

Explicit:

(a) Patient has a catheter and the catheter is used in the procedure.

Patient (X) $\xrightarrow{\text{Person has}}$ catheter (Y).

Procedure $\xrightarrow{\text{Procedure uses}}$ catheter (Y).

(b) Patient has a catheter, patient has a procedure, and that procedure uses that catheter.

Patient (X) $\xrightarrow{\text{Person has}}$ catheter (Y).

Patient (X) $\xrightarrow{\text{Person has}}$ procedure (Z).

Procedure (Z) $\xrightarrow{\text{Procedure uses}}$ catheter (Y).

Implicit:

(a) Patient has a catheter and patient has a procedure.

Patient (X) $\xrightarrow{\text{Person has}}$ catheter.

Patient (X) $\xrightarrow{\text{Person has}}$ procedure.

‡Need clinical knowledge to determine which procedure is likely to use or involve a specific type of catheter.

29 9a. Does patientC have an infection and catheter?

Explicit:

Patient (X) $\xrightarrow{\text{Person has}}$ infection.

Patient (X) $\xrightarrow{\text{Person has}}$ catheter.

Implicit:

‡Need clinical knowledge to determine if the observations combined indicate infection.

‡Need clinical knowledge to determine if the observations, anatomical locations, and/or procedures combined indicate a catheter is present.

39 9b. Was patientC's infection associated with a catheter?

§ Cannot determine if an infection is associated with a catheter unless that catheter is tested in the microbiology lab.

41
42
43
44
45
46
47
48
49
50
51

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51

A.3. AAENOTE CQ 1: Does patientA have phlebitis, and was it infectious phlebitis, chemical phlebitis, or mechanical phlebitis?

The patients who have phlebitis are listed in Table 7 using Listing 1. And anatomical locations with phlebitis in Table 8 were queried using Listing 2.

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
SELECT DISTINCT ?indv_patient ?class_phlebitis
WHERE {
  ?indv_patient rdf:type :patient ;
               rdf:type ?class_patient .
  FILTER(?class_patient != owl:NamedIndividual) .
  ?indv_phlebitis rdf:type* :phlebitis ;
                 rdf:type ?class_phlebitis .
  FILTER(?class_phlebitis != owl:NamedIndividual) .
  FILTER(REGEX(str(?class_phlebitis), "phlebitis")) .
  ?indv_patient :person_has ?indv_phlebitis .
}
ORDER BY ?indv_patient
    
```

Listing 1: Patient has phlebitis.

Table 7
AAENOTE SPARQL Query Result: List patients that have phlebitis

Query Result	Patient	Phlebitis
1	patient.T1.2.lo22a.SD_0003	✓
2	patient.T1.3.do13a.PO_0005	✓
3	patient.T2.2.do13a.SP_0008	✓
4	patient.T2.2.lo12a.SD_0003	✓
5	patient.T2.2.lo22a.PO_0005	✓
6	patient.T2.3.do23a.PO_0005	✓
7	patient.T2.3.po24a.SD_0003	✓
8	patient.T2.4.lo22a.SP_0008	✓
9	patient.T3.3.po14a.SD_0003	✓
10	patient.T4.1.po14a.PO_0005	✓

Query result 1-10: Patient $\xrightarrow{\text{Person has}}$ phlebitis.

```

1 PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
2 PREFIX owl: <http://www.w3.org/2002/07/owl#>
3 PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
4 PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
5 PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
6 SELECT DISTINCT ?indv_location ?class_phlebitis
7 WHERE {
8   ?indv_phlebitis rdf:type :phlebitis ;
9   rdf:type ?class_phlebitis .
10  FILTER(?class_phlebitis != owl:NamedIndividual) .
11  ?indv_location rdf:type/rdfs:subClassOf* :anatomical_location ;
12  rdf:type ?class_location .
13  FILTER(?class_location != owl:NamedIndividual) .
14  ?indv_phlebitis :located_nearby_on_at_in ?indv_location .
15 }
16 ORDER BY ?indv_location

```

Listing 2: List phlebitis located nearby/on/at/in an anatomical location.

Table 8
AAENOTE SPARQL Query Result: List phlebitis at an anatomical location

Query Result	Anatomical Location	Phlebitis
1	elbow.T1.4.lo22a.DO_0010	✓
2	elbow.T2.1.do13a.DO_0010	✓
3	elbow.T2.4.lo12a.DO_0010	✓
4	elbow.T3.3.so11a.DO_0010	✓
5	elbow.T3.3.so21a.DO_0010	✓
6	hand.T3.4.lo12a.SP_0008	✓
7	hand.T4.3.do13a.PO_0005	✓
8	hand.T7.2.lo22a.PO_0005	✓
9	wrist.T4.2.do13a.SP_0008	✓
10	patient.T4.1.po14a.PO_0005	✓

Query result 1-10: Listing 5 SPARQL query: Phlebitis
Located nearby/on/at/in anatomical location.

A.4. AAENOTE CQ 1: Does patientA have an infection?

A.4.1. AAENOTE CQ1 Explicit

The patients who have infection are listed in Table 9 using Listing 3. Whereas, patients who have infection and/or other observations are listed in Table 10 using Listing 4.

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
SELECT DISTINCT ?indv_patient ?class_infection
WHERE {
  ?indv_patient rdf:type :patient ;
               rdf:type ?class_patient .
  FILTER(?class_patient != owl:NamedIndividual) .
  ?indv_infection rdf:type* :infection ;
                 rdf:type ?class_infection .
  FILTER(?class_infection != owl:NamedIndividual) .
  FILTER(REGEX(str(?class_infection), "infection")) .
  ?indv_patient :person_has ?indv_infection .
}
ORDER BY ?indv_patient
    
```

Listing 3: List patients who have infection.

Table 9
AAENOTE SPARQL Query Result: List patients that have infection

Query Result	Patient	Infection
1	patient.T1.2.lo22a.SD_0006	✓
2	patient.T1.4.lo22a.SP_0002	✓
3	patient.T10.2.do23a.SP_0007	✓
4	patient.T12.4.lo12a.SP_0007	✓
5	patient.T2.2.do23a.SP_0006	✓
6	patient.T2.2.lo12a.SD_0006	✓
7	patient.T2.3.do23a.PO_0010	✓
8	patient.T2.3.po14a.SD_0006	✓
9	patient.T3.2.do13a.SP_0007	✓
10	patient.T4.4.lo22a.DO_0008	✓
11	patient.T4.4.so11a.DP_0010	✓
12	patient.T5.2.po24a.DO_0008	✓
13	patient.T5.4.lo22a.SP_0007	✓
14	patient.T7.3.po24a.SD_0006	✓

Query result 1-14: Patient $\xrightarrow{\text{Person has}}$ infection.

```

1 PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
2 PREFIX owl: <http://www.w3.org/2002/07/owl#>
3 PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
4 PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
5 PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
6 SELECT DISTINCT ?indv_patient ?observations
7 WHERE {
8   {
9     # Group ?class_observations alphabetically by ?indv_patient
10    SELECT ?indv_patient ?class_patient
11    (GROUP_CONCAT (DISTINCT str(?class_observation); separator=", " ) as ?observations)
12    WHERE {
13      # Organize alphabetically ?class_observations
14      SELECT ?indv_patient ?class_patient ?class_observation
15      WHERE {
16        ?indv_patient rdf:type :patient ;
17        rdf:type ?class_patient .
18        FILTER(?class_patient != owl:NamedIndividual) .
19        FILTER(REGEX(str(?class_patient), "patient")) .
20        ?indv_observation rdf:type/rdfs:subClassOf* :observation ;
21        rdf:type ?class_observation .
22        FILTER(?class_observation != owl:NamedIndividual) .
23        ?indv_patient :person_has ?indv_observation .
24      }
25      GROUP BY ?indv_patient ?class_patient ?class_observation
26      ORDER BY ?class_observation
27    }
28    GROUP BY ?indv_patient ?class_patient
29  }
30  FILTER REGEX(str(?observations), "infection")
31 }
32 ORDER BY ?indv_patient

```

Listing 4: List patients who have infection and/or other observations.

Table 10
AAENOTE SPARQL Query Result: List patients that have infection and/or another observation

Query Result	Person	Observation											
	Patient	blood pressure	body temp	c reactive protein	consciousness level	infection	neurological and physiological	observation	pulse	red	respiratory rate	sepsis	swollen
1	patient.T1.2.lo22a.SD_0006	✓	✓	✓		✓			✓				
2	patient.T1.4.lo22a.SP_0002		✓			✓					✓		
3	patient.T10.2.do23a.SP_0007				✓	✓							
4	patient.T12.4.lo12a.SP_0007				✓	✓		✓					
5	patient.T2.2.do23a.SP_0006					✓							
6	patient.T2.2.lo12a.SD_0006		✓	✓		✓							
7	patient.T2.3.do23a.PO_0010					✓				✓			
8	patient.T2.3.po14a.SD_0006	✓	✓	✓		✓	✓	✓	✓		✓		
9	patient.T3.2.do13a.SP_0007			✓	✓	✓		✓					
10	patient.T4.4.lo22a.DO_0008					✓				✓			✓
11	patient.T4.4.so11a.DP_0010					✓					✓		
12	patient.T5.2.po24a.DO_0008					✓				✓			✓
13	patient.T5.4.lo22a.SP_0007			✓		✓	✓						
14	patient.T7.3.po24a.SD_0006	✓	✓	✓		✓			✓			✓	

Query result 1-14: Patient $\xrightarrow{\text{Person has}}$ infection and other observation (s).

A.4.2. AAENOTE CQI Implicit

By using anatomical locations it is possible to implicitly identify infection within a patient because the anatomical locations refer to a place on a human and in the context of AE notes anatomical locations commonly refer to a place on a patient. As shown in Table 11, only 1 instance where infection is located at an anatomical location was found using either Listing 5 or Listing 6.

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
SELECT DISTINCT ?indv_location ?class_infection
WHERE {
  ?indv_infection rdf:type :infection ;
                 rdf:type ?class_infection .
  FILTER(?class_infection != owl:NamedIndividual) .
  ?indv_location rdf:type/rdfs:subClassOf* :anatomical_location ;
                 rdf:type ?class_location .
  FILTER(?class_location != owl:NamedIndividual) .
  ?indv_infection :located_nearby_on_at_in ?indv_location .
}
ORDER BY ?indv_location

```

Listing 5: List infection located nearby/on/at/in an anatomical location.

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
SELECT DISTINCT ?indv_location ?observations
WHERE {
  {
    SELECT ?indv_location ?class_location
      (GROUP_CONCAT (DISTINCT ?class_observation; separator=", " ) as ?observations)
    WHERE {
      {
        SELECT ?indv_location ?class_location ?class_observation
        WHERE {
          ?indv_observation rdf:type/rdfs:subClassOf* :observation ;
                           rdf:type ?class_observation .
          FILTER(?class_observation != owl:NamedIndividual) .
          ?indv_location rdf:type/rdfs:subClassOf* :anatomical_location ;
                           rdf:type ?class_location .
          FILTER(?class_location != owl:NamedIndividual) .
          ?indv_observation :located_nearby_on_at_in ?indv_location .
        }
        GROUP BY ?indv_location ?class_location ?class_observation
        ORDER BY ?class_observation
      }
    }
    GROUP BY ?indv_location ?class_location
    ORDER BY ?class_location
  }
  FILTER REGEX(str(?observations), "infection")
}
ORDER BY ?indv_location

```

Listing 6: List infection and other observations located nearby/on/at/in an anatomical location.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51

Table 11
AAENOTE SPARQL Query Result: List infections and/or observations at an anatomical location

Query Result	Anatomical Location	Infection
1	skin.T4.2.po14a.SL_0006	✓

Same results for Listing 5 and Listing 6 SPARQL query.
 Query result 1 from Listing 5 SPARQL query:
 Infection Located nearby/on/at/in anatomical location.
 Query result 1 from Listing 6 SPARQL query:
 Infection and other observation(s) Located nearby/on/at/in anatomical location.

1 A.5. AAENOTE CQ 2: Does patientA have a BSI? 1

2
3 Cannot determine if there is a BSI without a microbiology laboratory result of a positive blood culture and the 2
4 cultured bacteria name. 3
5

6 A.6. AAENOTE CQ 3: How many patients have an infection or BSI? 6

7
8 Explicitly, Table 4 shows the number of patients with infection and the number of patients with infection and/or 8
9 other observations (Listing 7). Implicitly, there was only 1 anatomical location that had infection (Appendix A.4.2), 9
10 so the results are not shown for the query in Listing 8. If there was clinical knowledge, it could provide the insight 10
11 required to determine if combinations of observations at certain anatomical locations are indications of an infection 11
12 (Listing 9 and Table 12). As previously stated in Appendix A.5, BSI cannot be determined because this requires 12
13 microbiology laboratory blood test results. 13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51

```

1 PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
2 PREFIX owl: <http://www.w3.org/2002/07/owl#>
3 PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
4 PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
5 PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
6
7 SELECT ?class_patient ?observations ?n_patients
8 WHERE {
9   {
10    SELECT ?class_patient
11      (GROUP_CONCAT (DISTINCT str(?class_observation); separator=", " ) as ?observations)
12      (COUNT (DISTINCT ?indv_patient ) as ?n_patients)
13    WHERE {
14      ?indv_patient rdf:type :patient ;
15        rdf:type ?class_patient .
16      FILTER(?class_patient != owl:NamedIndividual) .
17      ?indv_infection rdf:type :infection ;
18        rdf:type ?class_observation .
19      FILTER(?class_observation != owl:NamedIndividual) .
20      ?indv_patient :person_has ?indv_infection .
21    }
22    GROUP BY ?class_patient ?class_observation
23    ORDER BY ?class_observation
24  }
25  UNION
26  {
27    SELECT ?class_patient ?observations (COUNT (DISTINCT ?indv_patient ) as ?n_patients)
28    WHERE {
29      {
30        SELECT ?indv_patient ?class_patient
31          (GROUP_CONCAT (
32            DISTINCT str(?class_observation); separator=", " ) as ?observations)
33        WHERE {
34          SELECT ?indv_patient ?class_patient ?class_observation
35          WHERE {
36            ?indv_patient rdf:type :patient ;
37              rdf:type ?class_patient .
38            FILTER(?class_patient != owl:NamedIndividual) .
39            ?indv_observation rdf:type/rdfs:subClassOf* :observation ;
40              rdf:type ?class_observation .
41            FILTER(?class_observation != owl:NamedIndividual) .
42            ?indv_patient :person_has ?indv_observation .
43          }
44          GROUP BY ?indv_patient ?class_patient ?class_observation
45          ORDER BY ?class_observation
46        }
47        GROUP BY ?indv_patient ?class_patient
48      }
49      FILTER REGEX(str(?observations), "infection")
50    }
51    GROUP BY ?class_patient ?observations
52  }
53 }

```

Listing 7: Count the number of patients with infection and number patients with infection and other observations.

```

14 PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
15 PREFIX owl: <http://www.w3.org/2002/07/owl#>
16 PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
17 PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
18 PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
19 SELECT ?class_location ?observations (COUNT (DISTINCT ?indv_location) as ?n_instances)
20 WHERE {
21   {
22     SELECT ?indv_location ?class_location
23       (GROUP_CONCAT (DISTINCT ?class_observation; separator=", " ) as ?observations)
24     WHERE {
25       {
26         SELECT ?indv_location ?class_location ?class_observation
27         WHERE {
28           ?indv_observation rdf:type/rdfs:subClassOf* :observation ;
29           rdf:type ?class_observation .
30           FILTER(?class_observation != owl:NamedIndividual) .
31           ?indv_location rdf:type/rdfs:subClassOf* :anatomical_location ;
32           rdf:type ?class_location .
33           FILTER(?class_location != owl:NamedIndividual) .
34           ?indv_observation :located_nearby_on_at_in ?indv_location .
35         }
36         GROUP BY ?indv_location ?class_location ?class_observation
37         ORDER BY ?class_observation
38       }
39     }
40     GROUP BY ?indv_location ?class_location
41     ORDER BY ?class_location
42   }
43   FILTER REGEX(str(?observations), "infection")
44 }
45 GROUP BY ?class_location ?observations
46 ORDER BY ?class_location

```

Listing 8: Count the number of anatomical locations where infection and other observations are located nearby/on/at/in that anatomical location.

```

14 PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
15 PREFIX owl: <http://www.w3.org/2002/07/owl#>
16 PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
17 PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
18 PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
19 SELECT ?class_location ?observations (COUNT (DISTINCT ?indv_location) as ?n_instances)
20 WHERE {
21   {
22     SELECT ?indv_location ?class_location
23     (GROUP_CONCAT (DISTINCT ?class_observation; separator=", " ) as ?observations)
24     WHERE {
25       SELECT ?indv_location ?class_location ?class_observation
26       WHERE {
27         ?indv_observation rdf:type/rdfs:subClassOf* :observation ;
28         rdf:type ?class_observation .
29         FILTER(?class_observation != owl:NamedIndividual) .
30         ?indv_location rdf:type/rdfs:subClassOf* :anatomical_location ;
31         rdf:type ?class_location .
32         FILTER(?class_location != owl:NamedIndividual) .
33         ?indv_observation :located_nearby_on_at_in ?indv_location .
34       }
35       GROUP BY ?indv_location ?class_location ?class_observation
36       ORDER BY ?class_observation
37     }
38   }
39   GROUP BY ?indv_location ?class_location
40   ORDER BY ?class_location
41 }
42 GROUP BY ?class_location ?observations
43 ORDER BY ?class_location

```

Listing 9: Count the number of anatomical locations with the same observations located nearby/on/at/in that anatomical location.

Table 12
AAENOTE SPARQL Results for Anatomical Location with Combinations of Observations

Query Result	Instances	Anatomical Location				Observation										
		arm	elbow	hand	skin	body temp	edema	infection	mobility impairment	pain	phlebitis	purulence	red	swollen	warm	wound
1	12	✓								✓						
2	7	✓												✓		
3	6	✓										✓		✓		
4	4	✓								✓				✓		
5	3	✓								✓			✓	✓		
6	2	✓								✓			✓			
7	2	✓											✓			
8	1	✓								✓	✓					
9	1	✓								✓	✓		✓			
10	1	✓				✓			✓	✓		✓				
11	1	✓										✓				
12	1	✓										✓			✓	
13	1	✓					✓					✓				
14	1	✓										✓	✓	✓		
15	7		✓												✓	
16	7		✓									✓				
17	7		✓									✓	✓	✓		
18	6		✓							✓		✓	✓			
19	5		✓							✓			✓			
20	4		✓								✓					
21	3		✓											✓		
22	2		✓									✓			✓	
23	1		✓							✓						
24	1		✓									✓				
25	4			✓										✓		
26	3			✓							✓					
27	2			✓								✓	✓		✓	
28	1			✓						✓						
29	1			✓						✓				✓		
30	1			✓								✓	✓			
31	3				✓					✓						
32	3				✓									✓		
33	2				✓					✓				✓		
34	2				✓					✓			✓	✓		
35	2				✓							✓				
36	2				✓							✓	✓			
37	1				✓										✓	
38	1				✓			✓								
39	1				✓							✓		✓		
40	1				✓			✓				✓	✓			

Query result 1-40: Observation (s) Located nearby/on/at/in anatomical location.

A.7. AAENOTE CQ 4: Which patients have sepsis?

Explicitly, 5 patients have sepsis (Table 13, Listing 10) and 3 of the 5 patients with sepsis have sepsis and another observation (Table 14, Listing 11). Additional clinical knowledge is needed to determine if other observations combined without the sepsis class are indications of sepsis.

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
SELECT ?indv_patient ?class_sepsis
WHERE {
  ?indv_patient rdf:type :patient .
  ?indv_sepsis rdf:type :sepsis ;
              rdf:type ?class_sepsis .
  FILTER(?class_sepsis != owl:NamedIndividual) .
  ?indv_patient :person_has ?indv_sepsis .
}
ORDER BY ?indv_patient
    
```

Listing 10: List patients who have sepsis.

Table 13
AAENOTE SPARQL Query Result: List patients that have sepsis

Query Result	Patient	Sepsis
1	patient.T1.2.do13a.SP_0006	✓
2	patient.T1.4.lo12a.SP_0006	✓
3	patient.T6.3.lo22a.DP_0010	✓
4	patient.T7.2.po24a.SL_0004	✓
5	patient.T7.3.po24a.SD_0006	✓

Query result 1-5: Patient $\xrightarrow{\text{Person has}}$ sepsis.

Table 14
AAENOTE SPARQL Query Result: List patients that have sepsis and/or another observation

Query Result	Person Patient	Observation								
		blood pressure	body temp	c reactive protein	infection	pulse	red	respiratory rate	sepsis	swollen
1	patient.T1.2.do13a.SP_0006								✓	
2	patient.T1.4.lo12a.SP_0006								✓	
3	patient.T6.3.lo22a.DP_0010						✓	✓		
4	patient.T7.2.po24a.SL_0004		✓				✓	✓	✓	
5	patient.T7.3.po24a.SD_0006	✓	✓	✓	✓	✓			✓	

Query result 1-5: Patient $\xrightarrow{\text{Person has}}$ sepsis and other observation(s).

```

15 PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
16 PREFIX owl: <http://www.w3.org/2002/07/owl#>
17 PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
18 PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
19 PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
20 SELECT ?indv_patient ?observations
21 WHERE {
22   {
23     SELECT ?indv_patient ?class_patient
24     (GROUP_CONCAT (DISTINCT str(?class_observation); separator=", " ) as ?observations)
25     WHERE {
26       SELECT ?indv_patient ?class_patient ?class_observation
27       WHERE {
28         ?indv_patient rdf:type :patient ;
29         rdf:type ?class_patient .
30         FILTER(?class_patient != owl:NamedIndividual) .
31         ?indv_observation rdf:type/rdfs:subClassOf* :observation ;
32         rdf:type ?class_observation .
33         FILTER(?class_observation != owl:NamedIndividual) .
34         ?indv_patient :person_has ?indv_observation .
35       }
36       GROUP BY ?indv_patient ?class_patient ?class_observation
37       ORDER BY ?class_observation
38     }
39   }
40   GROUP BY ?indv_patient ?class_patient
41 }
42 FILTER REGEX(str(?observations), "sepsis")
43 }
44 ORDER BY ?indv_patient

```

Listing 11: List patients that have sepsis and/or other observations.

A.8. AAENOTE CQ 5: Does patientB have a catheter?

The patient and the type of catheter a patient has can be found explicitly using Listing 12. A subset of the results are in Table 15, where each patient individual is listed with a type of catheter and how many catheters of that specific type are present. Thus, the same patient can be listed multiple times as seen in Table 15's Query Result 28-30 where the same patient is listed 3 times because the patient has 3 catheters of different types. Implicitly, an anatomical location with a catheter indicates a person has a catheter (Listing 13, Table 16). Additional clinical knowledge is needed to determine if other observations combined indicate a catheter is present.

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
SELECT ?indv_patient ?class_catheter (COUNT (DISTINCT ?indv_catheter ) as ?n_catheters)
WHERE {
  ?indv_patient rdf:type :patient ;
               rdf:type ?class_patient .
  FILTER(?class_patient != owl:NamedIndividual) .
  ?indv_catheter rdf:type/rdfs:subClassOf* :catheter ;
                rdf:type ?class_catheter .
  FILTER(?class_catheter != owl:NamedIndividual) .
  ?indv_patient :person_has ?indv_catheter .
}
GROUP BY ?indv_patient ?class_catheter
ORDER BY ?indv_patient ?class_catheter

```

Listing 12: List patients that have a catheter, the catheter's type, and the number of that catheter type.

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
SELECT ?indv_location ?class_catheter
WHERE {
  ?indv_catheter rdf:type/rdfs:subClassOf* :catheter ;
                rdf:type ?class_catheter .
  FILTER(?class_catheter != owl:NamedIndividual) .
  ?indv_location rdf:type/rdfs:subClassOf* :anatomical_location ;
                 rdf:type ?class_location .
  FILTER(?class_location != owl:NamedIndividual) .
  ?indv_catheter :located_nearby_on_at_in ?indv_location .
}
ORDER BY ?indv_location

```

Listing 13: List the anatomical location and the type of catheter located nearby/on/at/in there.

Table 15
AAENOTE SPARQL Query Result: List of patients with a catheter

Query Result	Number of specific catheters	Person Patient	Catheter							
			catheter	central venous catheter	epidural catheter	hickman catheter	hemodialysis catheter	peripheral intravenous catheter	urinary catheter	vas catheter
1	1	patient.T1.1.lo12a.LO_0007						✓		
2	1	patient.T1.1.lo22a.LO_0007						✓		
3	1	patient.T1.1.lo22a.LO_0009					✓			
4	1	patient.T1.2.do13a.LO_0001						✓		
5	1	patient.T1.2.do13a.SP_0001							✓	
6	1	patient.T1.2.do13a.SP_0005						✓		
7	1	patient.T1.2.do13a.SP_0006						✓		
8	1	patient.T1.2.do13a.SP_0010						✓		
9	1	patient.T1.2.lo12a.PO_0005						✓		
10	1	patient.T1.2.lo12a.SD_0007								✓
11	1	patient.T1.2.lo22a.SD_0002						✓		
12	1	patient.T1.2.lo22a.SD_0007								✓
13	1	patient.T1.2.po24a.DO_0001		✓						
...										
22	1	patient.T1.4.lo12a.SP_0003		✓						
23	1	patient.T1.4.lo22a.DO_0003								✓
24	1	patient.T1.4.lo22a.SP_0005						✓		
25	1	patient.T1.4.lo22a.SP_0006						✓		
26	1	patient.T1.4.lo22a.SP_0010						✓		
27	1	patient.T1.4.po24a.LD_0004				✓				
28	1	patient.T1.4.po24a.LD_0009	✓							
29	1	patient.T1.4.po24a.LD_0009		✓						
30	1	patient.T1.4.po24a.LD_0009			✓					
...										
93	1	patient.T3.4.so11a.LO_0003								✓
94	1	patient.T3.4.so21a.LO_0004						✓		
95	2	patient.T4.1.lo22a.LO_0003						✓		
...										
138	1	patient.T9.2.so11a.LD_0003						✓		
139	1	patient.T9.3.po24a.SD_0005						✓		

Query result 1-139: Patient $\xrightarrow{\text{Person has}}$ catheter. And provide the specific type of catheter.
 Query result 28-30, same patient but different catheters.
 Query result 95, the patient has 2 PIVCs.

Table 16
AAENOTE SPARQL Query Result: List anatomical locations with catheters

Query Result	Anatomical Location Individuals under class	Catheter		
		catheter	venous catheter	peripheral intravenous catheter
1	arm.T14.3.po24a.SD_0002			✓
2	arm.T2.3.po24a.LO_0002			✓
3	arm.T2.3.po24a.SD_0001			✓
4	arm.T3.3.po24a.LO_0005			✓
5	arm.T5.3.po24a.LO_0004			✓
6	arm.T5.3.po24a.SD_0003			✓
7	arm.T5.3.so11a.DO_0002			✓
8	arm.T5.4.lo12a.DO_0003			✓
9	arm.T5.4.lo22a.DO_0003	✓		
	...			
14	arm.T9.4.lo12a.DO_0003			✓
15	body_part.T8.3.po14a.LO_0004			✓
16	elbow.T2.2.lo12a.SD_0001			✓
	...			
69	hand.T9.2.so21a.LD_0003			✓
70	navel.T5.3.so11a.LP_0010	✓		
71	navel.T5.4.do23a.LP_0010	✓		
72	skin.T11.3.po24a.LO_0001			✓
73	skin.T5.2.do23a.LO_0005			✓
74	subcutaneous.T12.2.do23a.LO_0004			✓
75	wrist.T2.2.do13a.LO_0005			✓
76	wrist.T3.2.do23a.LO_0005			✓
77	wrist.T3.4.so11a.LO_0005			✓
78	wrist.T7.3.po14a.LO_0005			✓

Query result 1-78: Catheter ^{Located nearby/on/at/in} anatomical location. And provide the specific anatomical location and type of catheter.

A.9. AAENOTE CQ 6: Does patientB have a PIVC?

This competency question (CQ) can be answered similarly to Appendix A.8. Explicitly using Listing 14 (Table 17) and implicitly using Listing 15 (Table 18). Likewise, additional clinical knowledge is needed to determine if other observations combined indicate a PIVC is present.

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
SELECT ?indv_patient ?class_pivc (COUNT (DISTINCT ?indv_pivc) as ?n_catheters)
WHERE {
  ?indv_patient rdf:type :patient ;
               rdf:type ?class_patient .
  FILTER(?class_patient != owl:NamedIndividual) .
  ?indv_pivc rdf:type/rdfs:subClassOf* :peripheral_intravenous_catheter ;
            rdf:type ?class_pivc .
  FILTER(?class_pivc != owl:NamedIndividual) .
  ?indv_patient :person_has ?indv_pivc .
}
GROUP BY ?indv_patient ?class_pivc
ORDER BY ?indv_patient
    
```

Listing 14: List patients that have a PIVC and number of PIVCs.

Table 17
AAENOTE SPARQL Query Result: List patients that have a PIVC

Query Result	Number of PIVCs	Patient	peripheral intravenous catheter
1	1	patient.T1.1.lo12a.LO_0007	✓
2	1	patient.T1.1.lo22a.LO_0007	✓
3	1	patient.T1.2.do13a.LO_0001	✓
4	1	patient.T1.2.do13a.SP_0005	✓
5	1	patient.T1.2.do13a.SP_0006	✓
		...	
31	1	patient.T2.1.lo22a.LO_0001	✓
32	2	patient.T2.1.lo22a.LO_0003	✓
33	1	patient.T2.2.do23a.LO_0001	✓
		...	
91	1	patient.T8.4.lo22a.SP_0010	✓
92	1	patient.T9.2.so11a.LD_0003	✓
93	1	patient.T9.3.po24a.SD_0005	✓

Query result 1-93: Patient $\xrightarrow{\text{Person has}}$ PIVC.

```

1 PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
2 PREFIX owl: <http://www.w3.org/2002/07/owl#>
3 PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
4 PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
5 PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
6 SELECT ?indv_location ?class_pivc
7 WHERE {
8   ?indv_pivc rdf:type/rdfs:subClassOf* :peripheral_intravenous_catheter ;
9     rdf:type ?class_pivc .
10  FILTER(?class_pivc != owl:NamedIndividual) .
11  ?indv_location rdf:type/rdfs:subClassOf* :anatomical_location ;
12     rdf:type ?class_location .
13  FILTER(?class_location != owl:NamedIndividual) .
14  ?indv_pivc :located_nearby_on_at_in ?indv_location .
15 }
16 ORDER BY ?indv_location

```

Listing 15: List anatomical locations with a PIVC.

Table 18
AAENOTE SPARQL Query Result: List anatomical locations with a PIVC

Query Result	Anatomical Location Individuals under class	Catheter peripheral intravenous catheter
1	arm.T14.3.po24a.SD_0002	✓
2	arm.T2.3.po24a.LO_0002	✓
3	arm.T2.3.po24a.SD_0001	✓
4	arm.T3.3.po24a.LO_0005	✓
5	arm.T5.3.po24a.LO_0004	✓
	...	
14	body_part.T8.3.po14a.LO_0004	✓
15	elbow.T2.2.lo12a.SD_0001	✓
16	elbow.T2.2.lo22a.SD_0001	✓
	...	
67	hand.T7.2.lo22a.PO_0005	✓
68	hand.T9.2.so21a.LD_0003	✓
69	skin.T11.3.po24a.LO_0001	✓
70	skin.T5.2.do23a.LO_0005	✓
71	subcutaneous.T12.2.do23a.LO_0004	✓
72	wrist.T2.2.do13a.LO_0005	✓
73	wrist.T3.2.do23a.LO_0005	✓
74	wrist.T3.4.so11a.LO_0005	✓
75	wrist.T7.3.po14a.LO_0005	✓

Query result 1-75: PIVC Located nearby/on/at/in anatomical location. And provide the specific anatomical location.

A.10. AAENOTE CQ 7a: How many catheters does patientB have?

Listing 16 is used to explicitly query the number and types of catheters a patient has as shown in Table 19. Sometimes there is a direct relationship between a person and multiple catheters such as in Query Result 28, 30, 45, and 52 of Table 19. Whereas, typically there is only one direct relationship between one catheter and an anatomical location when using the implicit query Listing 17 (Table 20). Similarly to Appendix A.6 where with clinical knowledge it could be possible to identify infection indications based on a combination of observations at a certain anatomical location, it could also be possible to determine if combinations of observations at certain anatomical locations are indications of a catheter.

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
# Group ?class_catheters alphabetically by ?indv_patient
SELECT ?indv_patient (GROUP_CONCAT (DISTINCT str(?class_catheter); separator=", " ) as ?catheters)
(COUNT (DISTINCT ?indv_catheter ) as ?n_catheters)
WHERE {
  {
    # Organize alphabetically ?class_catheter
    SELECT ?indv_patient ?indv_catheter ?class_catheter
    WHERE {
      ?indv_patient rdf:type :patient ;
        rdf:type ?class_patient .
      FILTER(?class_patient != owl:NamedIndividual) .
      ?indv_catheter rdf:type/rdfs:subClassOf* :catheter ;
        rdf:type ?class_catheter .
      FILTER(?class_catheter != owl:NamedIndividual) .
      ?indv_patient :person_has ?indv_catheter .
    }
    GROUP BY ?indv_patient ?indv_catheter ?class_catheter
    ORDER BY ?class_catheter
  }
}
GROUP BY ?indv_patient
ORDER BY ?indv_patient

```

Listing 16: Count the number of catheters a patient has and provide the types of catheters.

Table 19

AAENOTE SPARQL Query Result: List how many catheters and type of catheter a patient has

Query Results	Number of catheters	Person	Catheter								
		Patient	catheter	central venous catheter	epidural catheter	hickman catheter	hemodialysis catheter	peripheral intravenous catheter	urinary catheter	vas catheter	venous catheter
1	1	patient.T1.1.lo12a.LO_0007						✓			
2	1	patient.T1.1.lo22a.LO_0007						✓			
3	1	patient.T1.1.lo22a.LO_0009					✓				
4	1	patient.T1.2.do13a.LO_0001						✓			
5	1	patient.T1.2.do13a.SP_0001							✓		
6	1	patient.T1.2.do13a.SP_0005						✓			
7	1	patient.T1.2.do13a.SP_0006						✓			
8	1	patient.T1.2.do13a.SP_0010						✓			
9	1	patient.T1.2.lo12a.PO_0005						✓			
10	1	patient.T1.2.lo12a.SD_0007								✓	
11	1	patient.T1.2.lo22a.SD_0002						✓			
12	1	patient.T1.2.lo22a.SD_0007								✓	
13	1	patient.T1.2.po24a.DO_0001			✓						
			...								
26	1	patient.T1.4.lo22a.SP_0010						✓			
27	1	patient.T1.4.po24a.LD_0004						✓			
28	4	patient.T1.4.po24a.LD_0009	✓	✓	✓				✓		
29	1	patient.T1.4.po24a.SO_0009							✓		
30	2	patient.T1.4.so11a.DP_0002						✓	✓		
			...								
45	2	patient.T2.1.lo22a.LO_0003						✓			
46	1	patient.T2.2.do13a.SP_0003		✓							
47	1	patient.T2.2.do23a.LO_0001						✓			
48	1	patient.T2.2.do23a.LO_0007						✓			
49	1	patient.T2.2.do23a.SP_0006						✓			
50	1	patient.T2.2.lo22a.PO_0005						✓			
51	1	patient.T2.2.po14a.DO_0002						✓			
52	3	patient.T2.2.so11a.LD_0009	✓	✓					✓		
53	1	patient.T2.2.so11a.PO_0005						✓			
			...								
70	1	patient.T3.2.do23a.SP_0003		✓							
71	1	patient.T3.2.po14a.DO_0001			✓						
72	1	patient.T3.2.po14a.DO_0003								✓	
73	1	patient.T3.2.so11a.LD_0003						✓			
74	1	patient.T3.2.so11a.LD_0004			✓						
75	1	patient.T3.3.do13a.SL_0002						✓			
			...								
131	1	patient.T9.2.so11a.LD_0003						✓			
132	1	patient.T9.3.po24a.SD_0005						✓			

Query result 1-132: Patient $\xrightarrow{\text{Person has}}$ catheter. And count how many catheter (s) of a specific type the Patient has.

```

16 PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
17 PREFIX owl: <http://www.w3.org/2002/07/owl#>
18 PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
19 PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
20 PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
21 # Group ?class_catheters alphabetically by ?indv_location
22 SELECT ?indv_location (GROUP_CONCAT (DISTINCT str(?class_catheter); separator=", " ) as ?catheters)
23 (COUNT (DISTINCT ?indv_catheter ) as ?n_catheters)
24 WHERE {
25   {
26     # Organize alphabetically ?class_catheter
27     SELECT ?indv_location ?indv_catheter ?class_catheter
28     WHERE {
29       ?indv_catheter rdf:type/rdfs:subClassOf* :catheter ;
30       rdf:type ?class_catheter .
31       FILTER(?class_catheter != owl:NamedIndividual) .
32       ?indv_location rdf:type/rdfs:subClassOf* :anatomical_location ;
33       rdf:type ?class_location .
34       FILTER(?class_location != owl:NamedIndividual) .
35       ?indv_catheter :located_nearby_on_at_in ?indv_location .
36     }
37     GROUP BY ?indv_location ?indv_catheter ?class_catheter
38     ORDER BY ?class_catheter
39   }
40 }
41 GROUP BY ?indv_location
42 ORDER BY ?indv_location

```

Listing 17: Count the number of catheters located nearby/on/at/in an anatomical location and provide the types of catheters.

Table 20
AAENOTE SPARQL Query Result: List how many catheters and type of catheter an anatomical location has

Query Results	Number of catheters	Anatomical Location Individuals under class	Catheter		
			catheter	peripheral intravenous catheter	venous catheter
1	1	arm.T14.3.po24a.SD_0002		✓	
2	1	arm.T2.3.po24a.LO_0002		✓	
3	1	arm.T2.3.po24a.SD_0001		✓	
4	1	arm.T3.3.po24a.LO_0005		✓	
5	1	arm.T5.3.po24a.LO_0004		✓	
6	1	arm.T5.3.po24a.SD_0003		✓	
7	1	arm.T5.3.so11a.DO_0002		✓	
8	1	arm.T5.4.lo12a.DO_0003		✓	
9	1	arm.T5.4.lo22a.DO_0003			✓
		...			
14	1	arm.T9.4.lo12a.DO_0003		✓	
15	1	body_part.T8.3.po14a.LO_0004		✓	
16	1	elbow.T2.2.lo12a.SD_0001		✓	
		...			
67	1	hand.T6.3.do23a.PO_0005		✓	
68	1	hand.T7.2.lo22a.PO_0005		✓	
69	1	hand.T9.2.so21a.LD_0003		✓	
70	1	navel.T5.3.so11a.LP_0010	✓		
71	1	navel.T5.4.do23a.LP_0010	✓		
72	1	skin.T11.3.po24a.LO_0001		✓	
73	1	skin.T5.2.do23a.LO_0005		✓	
74	1	subcutaneous.T12.2.do23a.LO_0004		✓	
75	1	wrist.T2.2.do13a.LO_0005		✓	
76	1	wrist.T3.2.do23a.LO_0005		✓	
77	1	wrist.T3.4.so11a.LO_0005		✓	
78	1	wrist.T7.3.po14a.LO_0005		✓	

Query result 1-78: Catheter $\xrightarrow{\text{Located nearby/on/at/in}}$ anatomical location. And count how many catheter (s) of a specific type the specific anatomical location has.

A.11. AAENOTE CQ 7b: Where are the catheters in patientB?

Explicitly Listing 18 and Table 21. Implicitly, it is the same as Appendix A.8’s Listing 13 and Table 16 where catheter located at an anatomical location indicates a person has the catheter. Here also, additional clinical knowledge is needed to determine if other observations combined indicate a catheter is present.

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
SELECT ?indv_patient ?indv_catheter ?indv_location
WHERE {
  ?indv_patient rdf:type :patient ;
               rdf:type ?class_patient .
  FILTER(?class_patient != owl:NamedIndividual) .
  ?indv_catheter rdf:type/rdfs:subClassOf* :catheter ;
               rdf:type ?class_catheter .
  FILTER(?class_catheter != owl:NamedIndividual) .
  ?indv_location rdf:type/rdfs:subClassOf* :anatomical_location ;
               rdf:type ?class_location .
  FILTER(?class_location != owl:NamedIndividual) .
  ?indv_patient :person_has ?indv_catheter ;
               :person_has ?indv_location .
  ?indv_catheter :located_nearby_on_at_in ?indv_location .
}
ORDER BY ?indv_patient
    
```

Listing 18: List patients that have an anatomical location, a catheter, and the patient’s catheter is located nearby/on/at/in the patient’s anatomical location.

Table 21

AAENOTE SPARQL Query Result: Patient has an anatomical location, patient has a catheter, and that catheter is at the patient’s anatomical location.

Query Result	Patient	Catheter	Anatomical Location
1	patient.T1.4.lo22a.DO_0003	venous_catheter.T6.4.lo22a.DO_0003	arm.T5.4.lo22a.DO_0003
2	patient.T4.2.lo22a.SD_0003	peripheral_intravenous_catheter.T5.2.lo22a.SD_0003	hand.T6.2.lo22a.SD_0003

Query result 1-2: Patient (X) $\xrightarrow{\text{Person has}}$ anatomical location (Y), Patient (X) $\xrightarrow{\text{Person has}}$ Catheter (Z), and Catheter (Z) $\xrightarrow{\text{Located nearby/on/at/in}}$ anatomical location (Y).

A.12. AAENOTE CQ 7c: Why does patientB need the catheter(s)?

```

1  PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
2  PREFIX owl: <http://www.w3.org/2002/07/owl#>
3  PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
4  PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
5  PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
6  SELECT ?indv_patient ?class_catheter
7  (GROUP_CONCAT (DISTINCT str(?class_procedure); separator=", " ) as ?procedures)
8  WHERE {
9  {
10     SELECT ?indv_patient ?class_catheter ?class_procedure
11     WHERE {
12         ?indv_patient rdf:type :patient ;
13         rdf:type ?class_patient .
14         FILTER(?class_patient != owl:NamedIndividual) .
15         ?indv_catheter rdf:type/rdfs:subClassOf* :catheter ;
16         rdf:type ?class_catheter .
17         FILTER(?class_catheter != owl:NamedIndividual) .
18         ?indv_procedure rdf:type/rdfs:subClassOf* :procedure ;
19         rdf:type ?class_procedure .
20         FILTER(?class_procedure != owl:NamedIndividual) .
21         ?indv_patient :person_has ?indv_catheter .
22         ?indv_procedure :procedure_uses ?indv_catheter .
23     }
24     GROUP BY ?indv_patient ?class_catheter ?class_procedure
25     ORDER BY ?class_procedure
26 }
27 }
28 GROUP BY ?indv_patient ?class_catheter
29 ORDER BY ?indv_patient

```

Listing 19: List patients that have a catheter and the procedures which use that catheter.

Table 22
AAENOTE SPARQL Query Result: List patients that have a catheter which was used for a procedure

Query Results	Person	Catheter					Procedure									
	Patient	central venous catheter	epidural catheter	peripheral intravenous catheter	venous catheter	urinary catheter	administration purpose	catheter discontinue use	catheter rinse	catheter self removal	general iv	iv antibiotics	iv chemo	iv fluid	iv medication	iv nutrient
1	patient.T1.1.lo12a.LO_0007			✓							✓					
2	patient.T1.1.lo22a.LO_0007			✓							✓		✓			
3	patient.T1.2.do13a.LO_0001			✓							✓					
4	patient.T1.4.lo12a.DO_0003			✓			✓									
5	patient.T1.4.lo12a.SP_0003	✓												✓		
6	patient.T1.4.lo22a.DO_0003				✓		✓									
7	patient.T1.4.lo22a.SP_0010			✓							✓			✓		
8	patient.T1.4.so11a.DP_0002			✓					✓							
9	patient.T1.4.so11a.DP_0002					✓			✓							
10	patient.T1.4.so11a.LO_0001			✓							✓					
11	patient.T11.1.lo22a.LO_0004			✓								✓				
12	patient.T12.4.so11a.LO_0003				✓			✓								
13	patient.T2.2.do23a.LO_0007			✓							✓		✓			
14	patient.T2.3.so11a.LP_0007			✓					✓							
15	patient.T2.3.so21a.LP_0004			✓									✓			
16	patient.T2.4.lo22a.DO_0001	✓					✓									
17	patient.T2.4.so11a.DP_0001			✓											✓	
18	patient.T2.4.so11a.LO_0007			✓							✓					✓
19	patient.T3.2.so11a.LD_0003			✓									✓			
20	patient.T3.4.po24a.SO_0002			✓					✓					✓		
21	patient.T3.4.so11a.LO_0003				✓			✓								
22	patient.T4.3.po14a.SD_0005			✓					✓							
23	patient.T4.3.so11a.LP_0004			✓									✓			
24	patient.T5.3.po24a.LO_0003			✓				✓					✓			
25	patient.T5.4.lo12a.SP_0010			✓							✓					
26	patient.T6.1.lo22a.LO_0007			✓							✓		✓			
27	patient.T6.3.lo22a.DP_0001	✓								✓						
28	patient.T7.2.do23a.LO_0004			✓								✓				
29	patient.T7.3.po24a.SD_0007				✓			✓								
30	patient.T7.4.so11a.LO_0007			✓							✓					✓
31	patient.T8.4.lo22a.SP_0010			✓							✓					
32	patient.T9.3.po24a.SD_0005			✓					✓							

Query result 1-32: Patient $\xrightarrow{\text{Person has}}$ catheter (Y) and Procedure $\xrightarrow{\text{Procedure uses}}$ catheter (Y).

```

1 PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
2 PREFIX owl: <http://www.w3.org/2002/07/owl#>
3 PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
4 PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
5 PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
6 SELECT ?indv_patient ?class_catheter
7 (GROUP_CONCAT (DISTINCT str(?class_procedure); separator=", " ) as ?procedures)
8 WHERE {
9   {
10     SELECT ?indv_patient ?class_catheter ?class_procedure
11     WHERE {
12       ?indv_patient rdf:type :patient ;
13         rdf:type ?class_patient .
14       FILTER(?class_patient != owl:NamedIndividual) .
15       ?indv_catheter rdf:type/rdfs:subClassOf* :catheter ;
16         rdf:type ?class_catheter .
17       FILTER(?class_catheter != owl:NamedIndividual) .
18       ?indv_procedure rdf:type/rdfs:subClassOf* :procedure ;
19         rdf:type ?class_procedure .
20       FILTER(?class_procedure != owl:NamedIndividual) .
21       ?indv_patient :person_has ?indv_catheter ;
22         :person_has ?indv_procedure .
23       ?indv_procedure :procedure_uses ?indv_catheter .
24     }
25     GROUP BY ?indv_patient ?class_catheter ?class_procedure
26     ORDER BY ?class_procedure
27   }
28 }
29 GROUP BY ?indv_patient ?class_catheter
30 ORDER BY ?indv_patient

```

Listing 20: List patients that have a catheter, a procedure, and the patient’s procedure uses the patient’s catheter.

Table 23

AAENOTE SPARQL Query Result: List patients that have a catheter, have a procedure, and where the catheter was used for that procedure

Query Result	Person	Catheter	Procedure		
	Patient	peripheral intravenous catheter	iv antibiotics	iv fluid	iv medication
1	patient.T1.1.lo22a.LO_0007	✓	✓	✓	
2	patient.T1.4.lo22a.SP_0010	✓	✓		✓
3	patient.T2.2.do23a.LO_0007	✓	✓	✓	
4	patient.T6.1.lo22a.LO_0007	✓	✓	✓	

Query result 1-14: Patient (X) $\xrightarrow{\text{Person has}}$ catheter (Y), Patient (X) $\xrightarrow{\text{Person has}}$ procedure (Z), and Procedure (Z) $\xrightarrow{\text{Procedure uses}}$ catheter (Y).

```

15 PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
16 PREFIX owl: <http://www.w3.org/2002/07/owl#>
17 PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
18 PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
19 PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
20 SELECT ?indv_patient (GROUP_CONCAT (DISTINCT str(?class_catheter); separator=", " ) as ?catheters)
21 (GROUP_CONCAT (DISTINCT str(?class_procedure); separator=", " ) as ?procedures)
22 WHERE {
23   {
24     SELECT ?indv_patient ?class_catheter ?class_procedure
25     WHERE {
26       ?indv_patient rdf:type :patient ;
27       rdf:type ?class_patient .
28       FILTER(?class_patient != owl:NamedIndividual) .
29       ?indv_catheter rdf:type/rdfs:subClassOf* :catheter ;
30       rdf:type ?class_catheter .
31       FILTER(?class_catheter != owl:NamedIndividual) .
32       ?indv_procedure rdf:type/rdfs:subClassOf* :procedure ;
33       rdf:type ?class_procedure .
34       FILTER(?class_procedure != owl:NamedIndividual) .
35       ?indv_patient :person_has ?indv_catheter ;
36       :person_has ?indv_procedure .
37     }
38     GROUP BY ?indv_patient ?class_catheter ?class_procedure
39     ORDER BY ?class_catheter ?class_procedure
40   }
41 }
42 GROUP BY ?indv_patient
43 ORDER BY ?indv_patient

```

Listing 21: List patients that have a catheter and a procedure, and all catheters and all procedures the patient has.

Table 24
AAENOTE SPARQL Query Result: List patients that have a catheter and a procedure

Query Result	Person Patient	Catheter					Procedure							
		catheter	central venous catheter	hemodialysis catheter	peripheral intravenous catheter	urinary catheter	administration purpose	blood test	general iv	iv antibiotics	iv chemo	iv fluid	iv medication	procedure
1	patient.T1.1.lo22a.LO_0007				✓				✓					
2	patient.T1.1.lo22a.LO_0009			✓				✓						
3	patient.T1.2.do13a.SP_0001					✓								✓
4	patient.T1.2.do13a.SP_0010				✓				✓				✓	
5	patient.T1.2.lo22a.SD_0002				✓				✓			✓		
6	patient.T1.4.do13a.LP_0004				✓						✓			
7	patient.T1.4.lo22a.SP_0006				✓			✓						
8	patient.T1.4.lo22a.SP_0010				✓			✓		✓		✓		
9	patient.T12.2.lo22a.SD_0002				✓				✓					
10	patient.T15.3.po24a.SD_0002				✓				✓					
11	patient.T2.1.lo22a.LO_0001				✓				✓					
12	patient.T2.2.do13a.SP_0003		✓									✓		
13	patient.T2.2.do23a.LO_0001				✓				✓					
14	patient.T2.2.do23a.LO_0007				✓				✓		✓			
15	patient.T2.2.lo22a.PO_0005				✓									✓
16	patient.T2.3.do23a.PO_0005				✓									✓
17	patient.T3.2.do13a.LO_0007				✓				✓					
18	patient.T3.2.do23a.SP_0003		✓									✓		
19	patient.T3.3.lo22a.SO_0008	✓										✓		
20	patient.T3.3.po14a.SD_0002				✓							✓		
21	patient.T3.4.lo22a.SP_0003		✓									✓		
22	patient.T4.2.po24a.DO_0002				✓		✓							
23	patient.T5.2.do13a.LO_0003				✓						✓			
24	patient.T5.3.po24a.LO_0001				✓				✓					
25	patient.T6.1.lo22a.LO_0007				✓				✓		✓			
26	patient.T6.2.do13a.LO_0004				✓					✓				
27	patient.T6.4.do13a.LP_0002				✓		✓							
28	patient.T6.4.do23a.LP_0004				✓						✓			
29	patient.T8.4.lo22a.SP_0010				✓			✓						

Query result 1-29: Patient (X) $\xrightarrow{\text{Person has}}$ catheter and Patient (X) $\xrightarrow{\text{Person has}}$ procedure.

A.13. AAENOTE CQ 8a: Does patientC have an infection and catheter?

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.semanticweb.org/2022/04/aaenote#>
SELECT ?indv_patient ?class_catheter ?class_infection
WHERE {
  ?indv_patient rdf:type :patient ;
               rdf:type ?class_patient .
  FILTER(?class_patient != owl:NamedIndividual) .
  ?indv_catheter rdf:type/rdfs:subClassOf* :catheter ;
               rdf:type ?class_catheter .
  FILTER(?class_catheter != owl:NamedIndividual) .
  ?indv_infection rdf:type :infection ;
                 rdf:type ?class_infection .
  FILTER(?class_infection != owl:NamedIndividual) .
  ?indv_patient :person_has ?indv_catheter ;
               :person_has ?indv_infection .
}
ORDER BY ?indv_patient
    
```

Listing 22: List patients that have an infection and a catheter.

Table 25
 AAENOTE SPARQL Query Result: List patients that have an infection and a catheter

Query Result	Patient	peripheral intravenous catheter	infection
1	patient.T2.2.do23a.SP_0006	✓	✓

Query result 1: Patient (X) $\xrightarrow{\text{Person has}}$ infection and Patient (X) $\xrightarrow{\text{Person has}}$ catheter.

A.14. AAENOTE CQ 8b: Was patientC’s infection associated with a catheter?

Cannot determine if a patient’s infection is associated with a catheter unless that catheter is tested in the microbiology lab.

Appendix B. Catheter Infection Indications Ontology (CIIO) Assumptions, Indications, and Competency Questions

B.1. CIIO Assumptions

To address the competency questions (CQs) which ask about patients and not documents and alleviate the problem of patients being implicitly mentioned, 1 AE document represents 1 patient. In the actual electronic incident reporting system database, if the reported AE is related to a patient, there will be a patient ID. This allows users to know if the AE is about 1 patient, more than 1 patient, or no patients. Additionally, concepts that are documented within different sentences of the same document are likely describing concepts that occurred in the same event for the same patient. Furthermore, concepts documented in the same sentence that are linked together by a relationship are directly related. Certain relationships can provide the reason for why a concept was or is needed (i.e., procedureA Procedure uses deviceX, therefore deviceX was needed to perform procedureA).

B.2. Catheter and Infection Indications

B.2.1. Catheter Indications

1. A patient has a specific catheter documented.
2. Any IV usage or infusion indicates some type of catheter is used. IV usage includes general IV, IV medication, IV fluid, and IV antibiotics. Infusion includes infusion, intraosseous infusion, intravenous infusion, and subcutaneous infusion. Based on the type of IV usage or infusion alone, it is not enough to determine what type of catheter was used.
3. Catheter procedures indicate that a catheter is or was present because they require a catheter. Catheter procedures include catheter insertion, catheter discontinued use, catheter removal, catheter replacement, and catheter self-removal.
4. Infusion phlebitis indication indicates that some type of catheter is used.

B.2.2. Peripheral Intravenous Catheter (PIVC) Indications

1. PIVCs are rarely documented, so any PIVC explicitly documented indicates a PIVC was used or in use.
2. Leaking IV or an infusion at the arm, elbow, or hand indicates a PIVC is used. IV includes general IV, IV medication, IV fluid, and IV antibiotics. Infusion includes infusion, intraosseous infusion, intravenous infusion, and subcutaneous infusion. Central venous catheters (CVCs) are deep, so there should not have leakage on the skin. PIVC leakage typically occurs because the catheter dressing is not properly secured or the PIVC is placed near a movable joint (i.e., elbow) and becomes dislodged.

B.2.3. Epidural Indication

1. Epidural usage will explicitly be documented.
2. A epidural catheter is the only catheter located nearby/on/at/in the back (i.e., spinal cord).

B.2.4. Infusion phlebitis

As previously stated, infusion phlebitis can be mechanical, chemical, or infectious [18]. Regardless of cause, it is documented similarly and can either be a catheter-related infection or complication.

1. Early stage of infusion phlebitis is indicated by an insertion site or infusion with 2 of the following signs: (i) pain or tenderness, (ii) red, (iii) swollen or edema, or (iv) warm.
2. Medium stage of infusion phlebitis is indicated by (1) a vein with pain and (2) an insertion site or infusion with 2 signs: (i) red, (ii) swollen or edema, or (iii) warm.
3. Advanced stage of infusion phlebitis is indicated by (1) a vein with pain and hardness and (2) an insertion site or infusion with 2 signs: (i) red, (ii) swollen or edema, or (iii) warm.

B.2.5. Infection

1. Pus at an insertion site indicates an infection. Because pus present is a sure sign of infection.

B.2.6. Bloodstream Infection (BSI)

1. A bloodstream infection is indicated by a blood test with a positive test result and/or the name of the cultured bacteria.

B.2.7. Sepsis

1. Infection combined with mobility impairment, high body temperature, and frostbite indicates sepsis.
2. Meeting the Quick Sequential Organ Failure Assessment Score (qSOFA) [49] sepsis criteria is indicated if there is an infection indication and at least 2 of the following: (1) high respiratory rate, (2) low blood pressure, or (3) a consciousness level that is either confusion, verbally responsive, painfully responsive, or unresponsive.
3. Sepsis is indicated if there is an infection indication and the National Early Warning Score 2 (NEWS2) [50] criteria for clinical deterioration is met by a combination of (1) high respiratory rate, (2) low blood pressure, (3) high pulse, (4) low body temperature or high body temperature, and (5) consciousness level = confusion, verbally responsive, painfully responsive, or unresponsive.

B.3. CIO Competency Questions and Ontology Usage

Table 26: CIO Competency Questions and Ontology Usage

Competency Question	Ontology Classes and Relationships to Find Instances
1. Does patientA have phlebitis, and was it infectious phlebitis, chemical phlebitis, or mechanical phlebitis?	Early stage infusion phlebitis (a or b): (a) (pain or tenderness), red, (swollen or edema), warm $\xrightarrow{\text{Located nearby/on/at/in}}$ injection site. (b) Infusion $\xrightarrow{\text{Is observed with}}$ (pain or tenderness), red, (swollen or edema), warm. Medium stage infusion phlebitis (a) and (b or c): (a) (pain or tenderness) $\xrightarrow{\text{Located nearby/on/at/in}}$ vein. (b) red, (swollen or edema), warm $\xrightarrow{\text{Located nearby/on/at/in}}$ injection site. (c) Infusion $\xrightarrow{\text{Is observed with}}$ red, (swollen or edema), warm. Advanced stage infusion phlebitis: (a) hardness and (pain or tenderness) $\xrightarrow{\text{Located nearby/on/at/in}}$ vein. (b) red, (swollen or edema), warm $\xrightarrow{\text{Located nearby/on/at/in}}$ injection site. (c) Infusion $\xrightarrow{\text{Is observed with}}$ red, (swollen or edema), warm. ‡Need additional documentation or pathophysiology studies at the body's cellular or genetic-level to determine if the phlebitis is infectious phlebitis, chemical phlebitis, or mechanical phlebitis.
2. Does patientA have an infection?	Pus at an insertion site indicates infection. Sentence $\xrightarrow{\text{Contains}}$ pus and insertion site. Pus $\xrightarrow{\text{Located nearby/on/at/in}}$ insertion site.

1	3. Does patientA have a BSI?	Documentation with a blood test with (a) a positive test result and/or (b) name of cultured bacteria.	1
2			2
3		Sentence $\xrightarrow{\text{Contains}}$ blood test.	3
4		(a) Blood test $\xrightarrow{\text{Has blood test result}}$ Positive.	4
5		(b) Blood test $\xrightarrow{\text{Has cultured bacteria}}$ bacteria name (i.e., Streptococcus,	5
6		Staphylococcus, <i>S. aureus</i> , etc.).	6
7			7
8	4. How many patients have an infection or BSI?	Same as Competency Question 1 and 2.	8
9			9
10	5. Which patients have sepsis?	Sepsis is indicated by (a) an infection indication combined with (b): (1) mobility impairment, (2) high body temperature (i.e., hyperthermia), and (3) frostbite:	10
11			11
12		(a) Sentence $\xrightarrow{\text{Contains}}$ pus and insertion site.	12
13		Pus $\xrightarrow{\text{Located nearby/on/at/in}}$ insertion site.	13
14		(b) Sentence $\xrightarrow{\text{Contains}}$ mobility impairment, body	14
15		temperature, and frostbite.	15
16		Body temperature $\xrightarrow{\text{Has body temperature range}}$ hyperthermia.	16
17			17
18		Meeting the Quick Sequential Organ Failure Assessment Score (qSOFA)	18
19		criteria of (a) an infection indication and (b) at least 2 of the following:	19
20		(1) high respiratory rate, (2) low blood pressure, or (3) a consciousness	20
21		level that is either confusion, verbally responsive, painfully responsive, or	21
22		unresponsive:	22
23		(a) Sentence $\xrightarrow{\text{Contains}}$ pus and insertion site.	23
24		Pus $\xrightarrow{\text{Located nearby/on/at/in}}$ insertion site.	24
25		(b) Sentence $\xrightarrow{\text{Contains}}$ respiratory rate, blood	25
26		pressure, and/or consciousness level.	26
27		Respiratory rate $\xrightarrow{\text{Has severity}}$ high.	27
28		Blood pressure $\xrightarrow{\text{Has severity}}$ low.	28
29		Consciousness level $\xrightarrow{\text{Has consciousness state}}$ confusion, ver-	29
30		bally responsive, painfully responsive, or unresponsive.	30
31		Meeting (a) an infection indication and (b) the National Early Warning	31
32		Score 2 (NEWS2) criteria for clinical deterioration by having a combina-	32
33		tion of: (1) high respiratory rate, (2) low blood pressure, (3) high pulse, (4)	33
34		low body temperature or high body temperature (i.e., hypothermia or hy-	34
35		perthermia), and (5) consciousness level = confusion, verbally responsive,	35
36		painfully responsive, or unresponsive:	36
37		(a) Sentence $\xrightarrow{\text{Contains}}$ pus and insertion site.	37
38		Pus $\xrightarrow{\text{Located nearby/on/at/in}}$ insertion site.	38
39		(b) Sentence $\xrightarrow{\text{Contains}}$ respiratory rate, blood	39
40		pressure, pulse, body temperature, and/or	40
41		consciousness level.	41
42		Respiratory rate $\xrightarrow{\text{Has severity}}$ high.	42
43		Blood pressure $\xrightarrow{\text{Has severity}}$ low.	43
44		Pulse $\xrightarrow{\text{Has severity}}$ high.	44
45		Body temperature $\xrightarrow{\text{Has body temperature range}}$ hypothermia or hy-	45
46		perthermia.	46
47		Consciousness level $\xrightarrow{\text{Has consciousness state}}$ confusion, ver-	47
48		bally responsive, painfully responsive, or unresponsive.	48
49			49
50			50
51			51

6. Does patientB have a catheter?

Documentation of a specific catheter, IV usage, infusion, or catheter-related procedure:

Sentence $\xrightarrow{\text{Contains}}$ medical device(s) or IV-related, infusion-related, or catheter procedure-related procedures.

Early stage infusion phlebitis is indicated by (a) an injection site or (b) infusion with 2 of the following signs: (i) pain or tenderness, (ii) red, (iii) swollen or edema, or (iv) warm:

(a) Sentence $\xrightarrow{\text{Contains}}$ injection site and pain or tenderness, red, swollen or edema, and/or warm.

Pain or tenderness, red, swollen or edema, or warm $\xrightarrow{\text{Located nearby/on/at/in}}$ injection site.

(b) Sentence $\xrightarrow{\text{Contains}}$ infusion and pain or tenderness, red, swollen or edema, and/or warm.

Pain or tenderness, red, swollen or edema, or warm $\xrightarrow{\text{Is observed with}}$ infusion.

Medium stage infusion phlebitis is indicated by (a) a vein with pain or tenderness, and (b) an injection site or (c) infusion with 2 of the following signs: (i) red, (ii) swollen or edema, or (iii) warm:

(a) Sentence $\xrightarrow{\text{Contains}}$ vein and pain or tenderness.

Pain or tenderness $\xrightarrow{\text{Located nearby/on/at/in}}$ vein.

(b) Sentence $\xrightarrow{\text{Contains}}$ injection site and red, swollen or edema, and/or warm.

Red, swollen or edema, or warm $\xrightarrow{\text{Located nearby/on/at/in}}$ injection site.

(c) Sentence $\xrightarrow{\text{Contains}}$ infusion and pain or tenderness, red, swollen or edema, and/or warm.

Red, swollen or edema, or warm $\xrightarrow{\text{Is observed with}}$ infusion.

Advanced stage infusion phlebitis is indicated by (a) a vein with (i) hardness and (ii) pain or tenderness, and (b) an injection site or (c) infusion with 2 of the following signs: (i) red, (ii) swollen or edema, or (iii) warm:

(a) Sentence $\xrightarrow{\text{Contains}}$ vein, hardness, and pain or tenderness.

Hardness and pain or tenderness $\xrightarrow{\text{Located nearby/on/at/in}}$ vein.

(b) Sentence $\xrightarrow{\text{Contains}}$ injection site and red, swollen or edema, and/or warm.

Red, swollen or edema, or warm $\xrightarrow{\text{Located nearby/on/at/in}}$ injection site.

(c) Sentence $\xrightarrow{\text{Contains}}$ infusion and pain or tenderness, red, swollen or edema, and/or warm.

Red, swollen or edema, or warm $\xrightarrow{\text{Is observed with}}$ infusion.

7. Does patientB have a PIVC?

PIVCs are rarely documented, so any PIVC explicitly documented indicates a PIVC was used or in use:

Sentence $\xrightarrow{\text{Contains}}$ PIVC.

Leaking IV or infusion at the arm, elbow or hand indicates PIVC usage:

Sentence $\xrightarrow{\text{Contains}}$ leakage and IV-related or infusion-related procedures.

Leakage $\xrightarrow{\text{Is observed with}}$ IV-related or infusion-related procedures.

1	8a. How many catheters does patientB have?	Same as Competency Question 5's documentation of a specific catheter, IV usage, infusion, or catheter-related procedure:	1
2			2
3		Sentence $\xrightarrow{\text{Contains}}$ medical device(s) or IV-related,	3
4		infusion-related, or catheter procedure-related proce-	4
5		dures.	5
6		* The exact number of catheters per document cannot be counted be-	6
7		cause multiple sentences within the document could be describing the same	7
8		catheter and documented procedures can use the same catheter.	8
9			9
10	8b. Where are the catheters in patientB?	Medical device located nearby/on/at/in an anatomical location:	10
11		Sentence $\xrightarrow{\text{Contains}}$ anatomical location and medical	11
12		device.	12
13		Medical device $\xrightarrow{\text{Located nearby/on/at/in}}$ anatomical	13
14		location.	14
15		IV usage, infusion, or catheter-related procedure located nearby/on/at/in an	15
16		anatomical location:	16
17		Sentence $\xrightarrow{\text{Contains}}$ anatomical location and IV-related,	17
18		infusion-related, or catheter procedure-related proce-	18
19		dures.	19
20		IV-related, infusion-related, or catheter procedure-	20
21		related procedures $\xrightarrow{\text{Located nearby/on/at/in}}$ anatomical	21
22		location.	22
23		* The exact anatomical location of catheters per document cannot be deter-	23
24		mined because multiple sentences within a document could be describing	24
25		the same catheter at the same location but with more general terms (i.e.,	25
26		arm instead of hand), the location's position was not documented (e.g., If a	26
27		sentence contains elbowA, right handB, and right armC, then handB is part	27
28		of armC, but elbowA might or might not be part of armC), multiple proce-	28
29		dures can be performed at the same location, and an additional anatomical	29
30	8c. Why does patientB need the catheter(s)?	The medical device is needed and used in a specific procedure.	30
31		Sentence $\xrightarrow{\text{Contains}}$ medical device and procedure.	31
32		Procedure $\xrightarrow{\text{Procedure uses}}$ medical device.	32
33		Document has sentences with medical devices and/or procedures:	33
34		Sentence $\xrightarrow{\text{Contains}}$ medical device and/or procedure.	34
35			35
36		* The exact reason cannot be determined unless the $\xrightarrow{\text{Procedure uses}}$ object	36
37		property links procedure and medical device because the indica-	37
38		tions do not provide a list of reasons for why a specific catheter can be used.	38
39		However, a clinician can view the retrieved list of devices and procedures	39
40		to determine if the devices in a document could be used for the procedures	40
41		documented.	41
42	9a. Does patientC have an infection and catheter?	Document with (a) infection indication and (b) (c) catheter indication :	42
43		(a) Sentence $\xrightarrow{\text{Contains}}$ pus and insertion site.	43
44		Pus $\xrightarrow{\text{Located nearby/on/at/in}}$ insertion site.	44
45		(b) Sentence $\xrightarrow{\text{Contains}}$ medical device.	45
46		(c) Sentence $\xrightarrow{\text{Contains}}$ anatomical location and IV-related,	46
47		infusion-related, or catheter procedure-related proce-	47
48		dures.	48
49	9b. Was patientC's infection associated with a	§ Cannot determine if an infection is associated with a catheter unless that	49
50	catheter?	catheter is tested in the microbiology lab.	50
51			51

References

- [1] M.Y. Yan, L.H. Høvik, L.T. Gustad and Ø. Nytrø, Understanding and Reasoning About Early Signs of Sepsis: From Annotation Guideline to Ontology, in: *2021 IEEE International Conference on Bioinformatics and Biomedicine (BIBM)*, 2021, pp. 1906–1911. doi:<https://doi.org/10.1109/BIBM52615.2021.9669311>.
- [2] M.Y. Yan, L.H. Høvik, A. Pedersen, L.T. Gustad and Ø. Nytrø, Preliminary Processing and Analysis of an Adverse Event Dataset for Detecting Sepsis-Related Events, in: *2021 IEEE International Conference on Bioinformatics and Biomedicine (BIBM)*, 2021, pp. 1605–1610. doi:<https://doi.org/10.1109/BIBM52615.2021.9669410>.
- [3] Ö. Uzuner, B.R. South, S. Shen and S.L. DuVall, 2010 i2b2/VA challenge on concepts, assertions, and relations in clinical text, *J. Am. Med. Inform. Assoc.* **18**(5) (2011), 552–556.
- [4] C.J. Mungall, C. Torniai, G.V. Gkoutos, S.E. Lewis and M.A. Haendel, Uberon, an integrative multi-species anatomy ontology, *Genome Biol.* **13**(1) (2012), R5.
- [5] M. Bada, M. Eckert, M. Palmer and L. Hunter, An Overview of the CRAFT Concept Annotation Guidelines, in: *Proceedings of the Fourth Linguistic Annotation Workshop*, Association for Computational Linguistics, Uppsala, Sweden, 2010, pp. 207–211.
- [6] M. Bada, N. Vasilevsky, W.A. Baumgartner, M. Haendel and L.E. Hunter, Gold-standard ontology-based anatomical annotation in the CRAFT Corpus, *Database* **2017** (2017).
- [7] B. Smith, W. Ceusters, B. Klagges, J. Köhler, A. Kumar, J. Lomax, C. Mungall, F. Neuhaus, A.L. Rector and C. Rosse, Relations in biomedical ontologies, *Genome Biol.* **6**(5) (2005), R46. doi:<https://doi.org/10.1186/gb-2005-6-5-r46>.
- [8] M. Bada and L. Hunter, Desiderata for ontologies to be used in semantic annotation of biomedical documents, *J. Biomed. Inform.* **44**(1) (2011), 94–101.
- [9] R.S. Trivillian, T. Adamusiak, T. Burdett, M. Gruenberger, J. Hancock, A.-M. Mallon, J. Malone, P. Schofield and H. Parkinson, Anatomy ontologies and potential users: bridging the gap, *J. Biomed. Semantics* **2 Suppl 4** (2011), S3. doi:<https://dx.doi.org/10.1186/2F2041-1480-2-S4-S3>.
- [10] C. Rosse and J.L.V. Mejino Jr, A reference ontology for biomedical informatics: the Foundational Model of Anatomy, *J. Biomed. Inform.* **36**(6) (2003), 478–500. doi:[10.1016/j.jbi.2003.11.007](https://doi.org/10.1016/j.jbi.2003.11.007).
- [11] C. Rosse and J.L.V. Mejino, The Foundational Model of Anatomy Ontology, in: *Anatomy Ontologies for Bioinformatics: Principles and Practice*, A. Burger, D. Davidson and R. Baldock, eds, Springer London, London, 2008, pp. 59–117.
- [12] O. Bodenreider, The Unified Medical Language System (UMLS): integrating biomedical terminology, *Nucleic Acids Res.* **32**(Database issue) (2004), D267–70. doi:<http://dx.doi.org/10.1093/nar/gkh061>.
- [13] L. Amos, D. Anderson, S. Brody, A. Ripple and B.L. Humphreys, UMLS users and uses: a current overview, *J. Am. Med. Inform. Assoc.* (2020). doi:<http://dx.doi.org/10.1093/jamia/ocaa084>.
- [14] A.R. Aronson, Effective mapping of biomedical text to the UMLS Metathesaurus: the MetaMap program, *Proc. AMIA Symp.* (2001), 17–21.
- [15] E. Alexandrou, G. Ray-Barruel, P.J. Carr, S.A. Frost, S. Inwood, N.S. Higgins, F. Lin, L. Alberto, L.A. Mermel and C.M. Rickard, Use of Short Peripheral Intravenous Catheters: Characteristics, Management, and Outcomes Worldwide, *J. of Hospital Med.* **13** 5 (2018). doi:[10.12788/jhm.3039](https://doi.org/10.12788/jhm.3039).
- [16] C. Dendle, R.L. Stuart and D. Egerton-Warburton, Think before you insert an intravenous catheter, *Med. J. Aust.* **199**(10) (2013), 655. doi:[10.5694/mja13.10733](https://doi.org/10.5694/mja13.10733).
- [17] G. Ray-Barruel, D.F. Polit, J.E. Murfield and C.M. Rickard, Infusion phlebitis assessment measures: a systematic review, *J. Eval. Clin. Pract.* **20**(2) (2014), 191–202.
- [18] R. Higginson and A. Parry, Phlebitis: treatment, care and prevention, *Nurs. Times* **107**(36) (2011), 18–21.
- [19] L. Zhang, S. Cao, N. Marsh, G. Ray-Barruel, J. Flynn, E. Larsen and C.M. Rickard, Infection risks associated with peripheral vascular catheters, *J. of Infection Prevention* **17**(5) (2016), 207–213. doi:[10.1177/1757177416655472](https://doi.org/10.1177/1757177416655472).
- [20] L.E. Huerta and T.W. Rice, Pathologic Difference between Sepsis and Bloodstream Infections, *The Journal of Applied Laboratory Medicine* **3**(4) (2019), 654–663. doi:[10.1373/jalm.2018.026245](https://doi.org/10.1373/jalm.2018.026245).
- [21] J. Paulsen, A. Mehl, Å. Askim, E. Solligård, B.O. Åsvold and J.K. Damås, Epidemiology and outcome of Staphylococcus aureus bloodstream infection and sepsis in a Norwegian county 1996–2011: an observational study, *BMC Infectious Diseases* **15** (2015), 116. doi:[10.1186/s12879-015-0849-4](https://doi.org/10.1186/s12879-015-0849-4).
- [22] K.E. Rudd, N. Kissoon, D. Limmathurotsakul, S. Bory, B. Muthunga, C.W. Seymour, D.C. Angus and T.E. West, The global burden of sepsis: barriers and potential solutions, *Crit. Care* **22**(1) (2018), 232. doi:[10.1186/s13054-018-2157-z](https://doi.org/10.1186/s13054-018-2157-z).
- [23] L.A. Mermel, Short-term Peripheral Venous Catheter-Related Bloodstream Infections: A Systematic Review, *Clin. Infectious Diseases* **65**(10) (2017), 1757–1762. doi:[10.1093/cid/cix562](https://doi.org/10.1093/cid/cix562).
- [24] J.M. Rohde, A.J. Odden, C. Bonham, L. Kuhn, P.N. Malani, L.M. Chen, S.A. Flanders and T.J. Iwashyna, The epidemiology of acute organ system dysfunction from severe sepsis outside of the intensive care unit, *J. of Hospital Med.* **8**(5) (2013), 243–247. doi:[10.1002/jhm.2012](https://doi.org/10.1002/jhm.2012).
- [25] Infectious Disease Ontology, 2017. <https://bioportal.bioontology.org/ontologies/IDO>.
- [26] Ontology for General Medical Science, 2021. <http://www.obofoundry.org/ontology/ogms>.
- [27] Vital Sign Ontology, 2012. <https://bioportal.bioontology.org/ontologies/VSO>.
- [28] A. Goldfain, B. Smith, S. Arabandi, M. Brochhausen and W.R. Hogan, Vital Sign Ontology, in: *Proc. of the Workshop on Bio-Ontologies*, 2011.
- [29] Foundational Model of Anatomy, 2008. <http://si.washington.edu/projects/fma>.
- [30] Biological Spatial Ontology, 2020. <http://obofoundry.org/ontology/bspo>.
- [31] Ontology of Adverse Events, 2021. <http://www.obofoundry.org/ontology/oa>.
- [32] Y. He, S. Sarntivijai, Y. Lin, Z. Xiang, A. Guo, S. Zhang, D. Jagannathan, L. Toldo, C. Tao and B. Smith, OAE: The Ontology of Adverse Events, *J. Biomed. Semantics* **5** (2014), 29.
- [33] Relation Ontology, 2021. <http://obofoundry.org/ontology/ro>.
- [34] National Cancer Institute Thesaurus. <https://bioportal.bioontology.org/ontologies/NCIT>.
- [35] NCI Thesaurus. <https://ncithesaurus.nci.nih.gov/ncitbrowser/>.

- [36] eHealth & International Classification for Nursing Practice (ICNP™), 2021. <https://www.icn.ch/what-we-do/projects/ehealth-icnptm>.
- [37] H.K. Butcher, G.M. Bulechek, J.M. Dochterman and C.M. Wagner, *Nursing Interventions Classification (NIC)*, Elsevier, 2018.
- [38] T. Heather Herdman, S. Kamitsuru and C.T. Lopes, *NANDA International Nursing Diagnoses: Definitions & Classification, 2021-2023*, Thieme Medical Publishers, Incorporated, 2021.
- [39] A. Jackson, Infection control—a battle in vein: infusion phlebitis, *Nurs. Times* **94**(4) (1998), 68, 71–.
- [40] Infusion Nurses Society, 2021 Infusion Therapy Standards of Practice Updates, *J. Infus. Nurs.* **44**(4) (2021), 189–190.
- [41] P. Stenetorp, S. Pyysalo, G. Topić, T. Ohta, S. Ananiadou and J. Tsujii, BRAT: a Web-based Tool for NLP-assisted Text Annotation, in: *Proc. Demonstrations at 13th Conf. EACL 2012*, 2012, pp. 102–107.
- [42] R. Salomão, B.L. Ferreira, M.C. Salomão, S.S. Santos, L.C.P. Azevedo and M.K.C. Brunialti, Sepsis: evolving concepts and challenges, *Braz. J. Med. Biol. Res.* **52**(4) (2019), e8595. doi:10.1590/1414-431X20198595.
- [43] K.N. Iskander, M.F. Osuchowski, D.J. Stearns-Kurosawa, S. Kurosawa, D. Stepien, C. Valentine and D.G. Remick, Sepsis: multiple abnormalities, heterogeneous responses, and evolving understanding, *Physiol. Rev.* **93**(3) (2013), 1247–1288. doi:10.1152/physrev.00037.2012.
- [44] J. Kolikof, K. Peterson and A.M. Baker, Central Venous Catheter, in: *StatPearls*, StatPearls Publishing, Treasure Island (FL), 2021.
- [45] H.J. White and M.P. Soos, Anatomy, Thorax, Superior Vena Cava, in: *StatPearls*, StatPearls Publishing, Treasure Island (FL), 2021.
- [46] L.H. Høvik, K.H. Gjeilo, S. Lydersen, C.M. Rickard, B. Røtvold, J.K. Damås, E. Solligård and L.T. Gustad, Monitoring quality of care for peripheral intravenous catheters; feasibility and reliability of the peripheral intravenous catheters mini questionnaire (PIVC-miniQ), *BMC Health Serv. Res.* **19**(1) (2019), 636.
- [47] M. Villegas, A. Intxaurreondo, A. Gonzalez-Agirre, M. Marimon and M. Krallinger, The MeSpEN resource for English-Spanish medical machine translation and terminologies: Census of parallel corpora, glossaries and term translations, in: *Proceedings of the LREC 2018 Workshop “MultilingualBIO: Multilingual Biomedical Text Processing”*, European Language Resources Association (ELRA), 2018.
- [48] D. Garijo, WIDOCO: a wizard for documenting ontologies, in: *International Semantic Web Conference*, Springer, Cham, 2017, pp. 94–102. doi:10.1007/978-3-319-68204-4_9.
- [49] C.W. Seymour, V.X. Liu, T.J. Iwashyna, F.M. Brunkhorst, T.D. Rea, A. Scherag, G. Rubenfeld, J.M. Kahn, M. Shankar-Hari, M. Singer, C.S. Deutschman, G.J. Escobar and D.C. Angus, Assessment of Clinical Criteria for Sepsis: For the Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3), *JAMA* **315**(8) (2016), 762–774.
- [50] Royal College of Physicians, National Early Warning Score (NEWS) 2: Standardising the assessment of acute-illness severity in the NHS. Updated report of a working party, Technical Report, Royal College of Physicians, 2017.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51