OMOP-2-OPMI: Ontologization of OMOP CDM using OPMI to support clinical data interoperability and analysis

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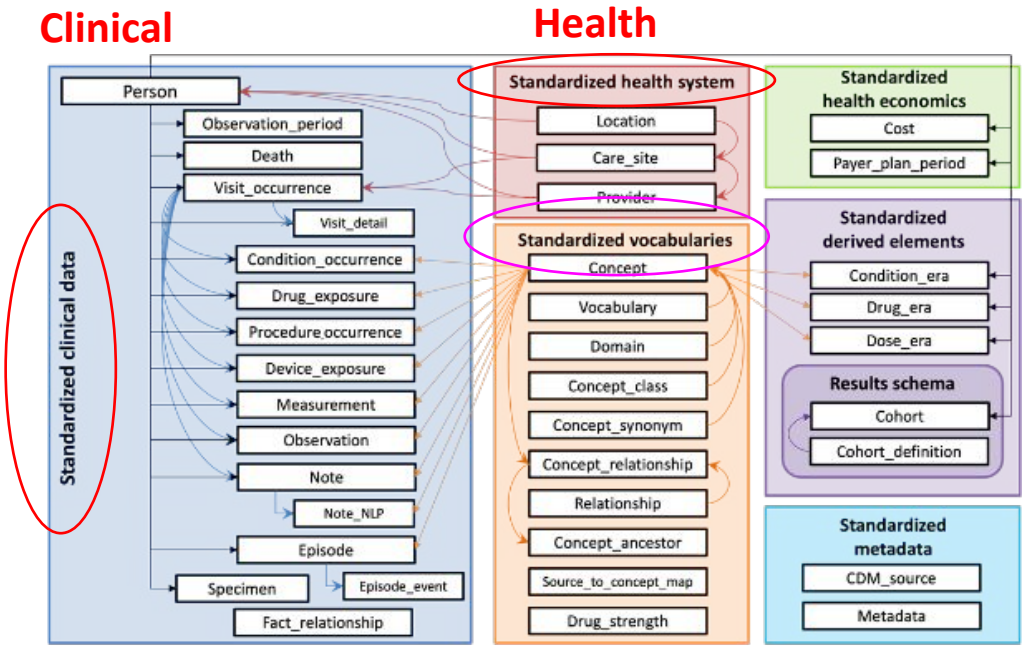
OMOP CDM

- OMOP: Observational Medical Outcomes Partnership
  - Developed by OHDSI
  - >1 billion patient records
- OMOP Common Data Model (**CDM**): allows for **integration** of different observational databases
  - Current version: CDM v5.4
- Used by National COVID Cohort Collaborative (**N3C,** https://ncats.nih.gov/n3c) and many other scenarios



https://ohdsi.github.io/CommonDataModel/

http://ohdsi.github.io/CommonDataModel/cdm54.html

https://link.springer.com/article/10.1007/s40273-020-00981-9

Bottlenecks of OMOP CDM

- **Weak semantics:** OMOP CDM provides database schema, which is powerful but lacks robust semantic relations among terms.
- **Poor interoperability** among CDMs
  - Other clinical CDMs exist: pcornet, cdisc, etc.
  - Difficult to support data standardization among databases with different CDMs.

- Ontology can be a solution to solve these bottlenecks
  - **Open Biomedical Ontology (OBO)** such as **OPMI** is our solution.

Our strategy: OMOP-2-OPMI

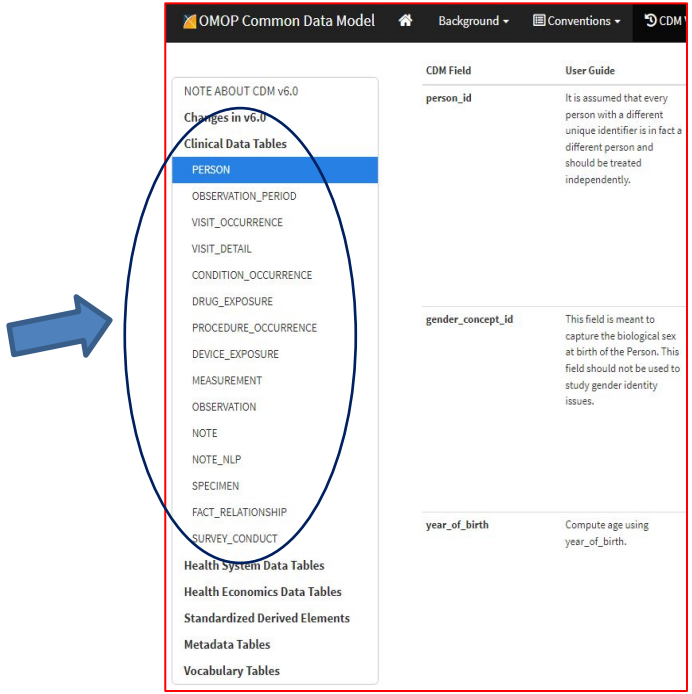
- OMOP2OBO is good but not enough

  https://github.com/callahantiff/OMOP2OBO

  - Maps to 8 OBO ontologies, e.g., Human Phenotype Ont. (HP), and MONDO disease Ont., etc.
  - Does not cover higher level CDM structure of OMOP
  - Does not cover contents of >10 clinical data tables and their relations.
  - Many CDM terms are not yet available in OBO ontologies → so new development is needed.

- OPMI:

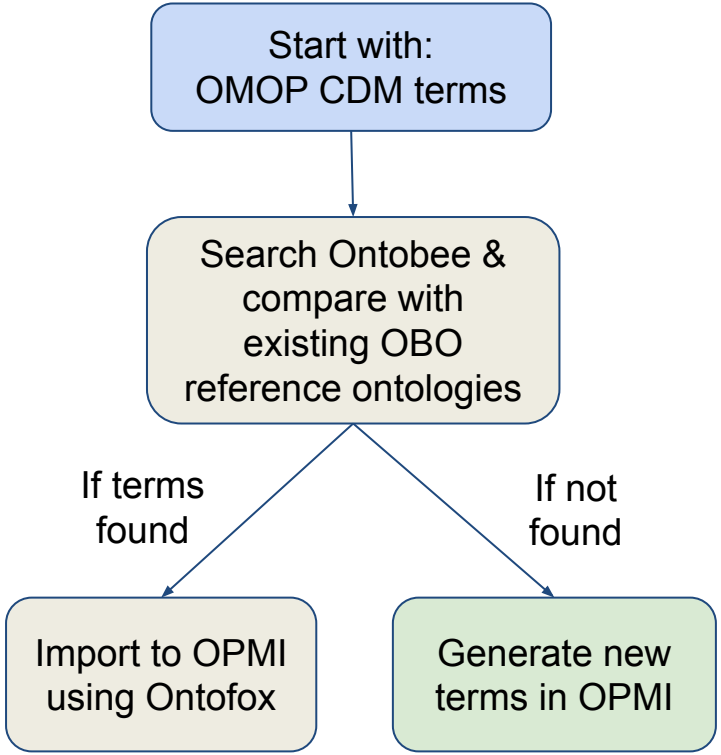
  - Ontology of Precision Medicine and Investigation
  - An OBO library ontology
  - Used for KPMP (Kidney Precision Medicine Project)
  - **Goal**: use OPMI to map and analyze OMOP CDM.



http://ohdsi.github.io/CommonDataModel/cdm60.htm

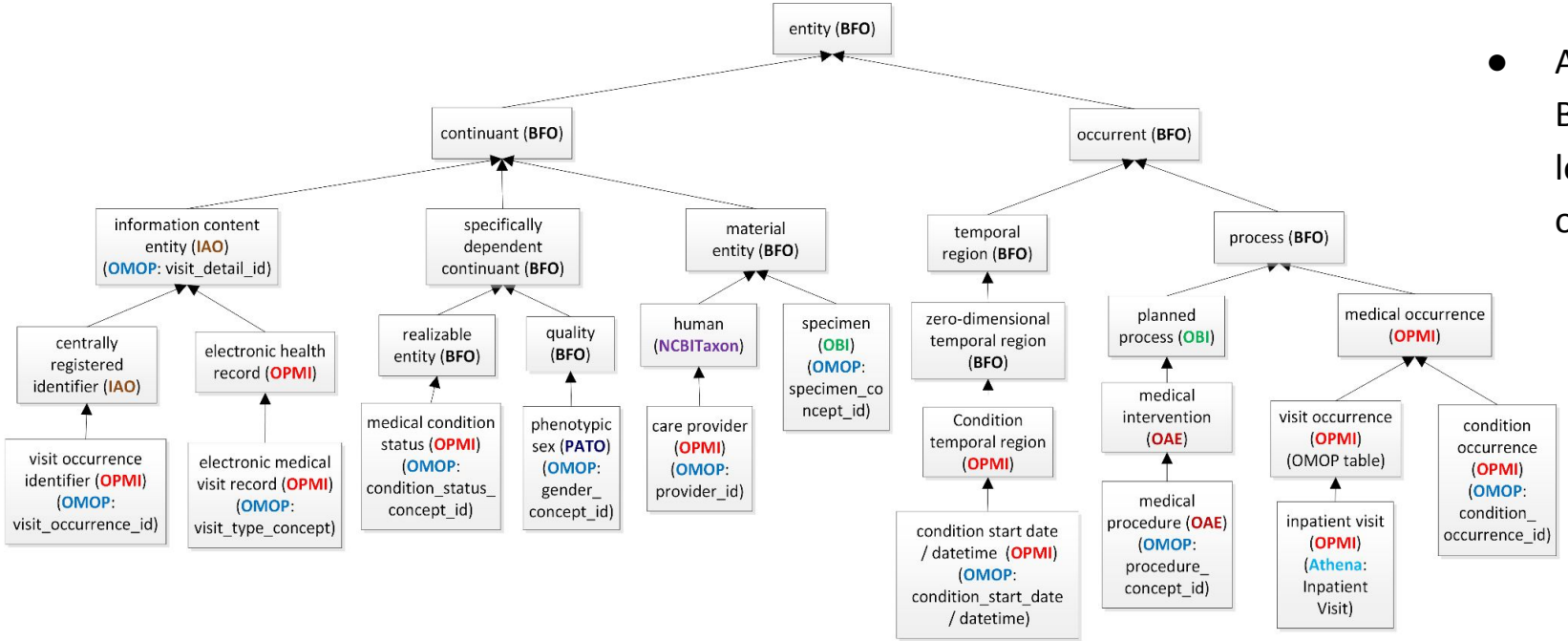
OMOP-2-OPMI Mapping Strategy & Workflow

- Source: OMOP CDM v5.4:
  - https://ohdsi.github.io/CommonDataModel/cdm54.html
- Mapping strategy:
  - Use Ontobee to find OMOP CDM terms from OBO ontologies
  - If existed in OBO ontologies, import using Ontofox
  - If new, create new OPMI terms and annotation.



OMOP-2-OPMI: Mapping OMOP CDM to OPMI

- OMOP-2-OPMI ontologizes all terms of OMOP CDM.
- Available on GitHub: https://raw.githubusercontent.com/OPMI/opmi/master/src/ontology/omop2opmi.owl



- Aligned with BFO upper level ontology

Figure 1

Simplified high level OMOP-2-OPMI ontology design pattern (ODP)

- ‘Person’ usually refers to Patients in OMOP
  - centric to OMOP CDM
  - mapped to NCBITaxon:human
- ‘Person’ participates in:
  - 5 medical occurrences
  - Observation process
- ‘Person’ can be a target of:
  - Measurement
- ‘Specimen’ is mapped to OBI:specimen

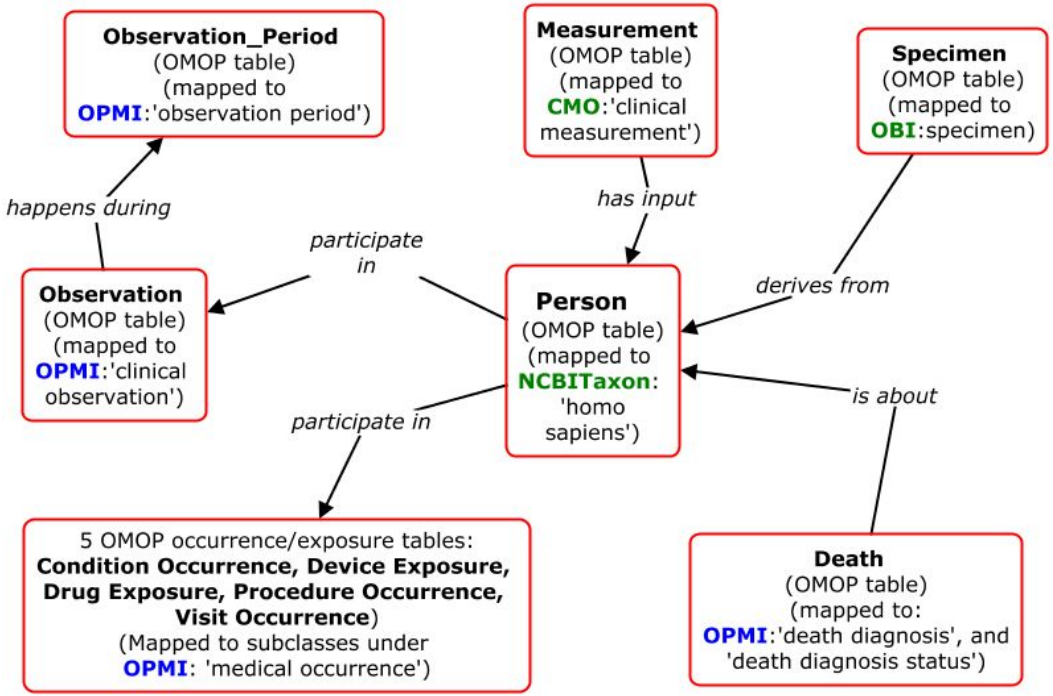


Figure 2

CDM terms from OMOP tables mapped to OPMI

- Statistics:
  - **165 terms** from **15 OMOP tables** mapped
  - 46 newly generated terms
- Current mapping:
  - **Clinical** data tables
  - **Health** system data tables
- Not yet included:
  - Non-clinically relevant tables (e.g., Standardized Metadata, Standardized Vocabularies, Standardized Derived Elements, etc.)

Table 1. terms from 10 representative OMOP tables

Selected OMOP tables	Mapped OMOP terms	Mapped Ontology Term Examples
PERSON	13/19*	person ID (OPMI_0000470), gender (PATO_0001894), year of birth (OPMI_0000473), race (NCIT_C17049)
PROVIDER	9/13	care provider (OPMI_0000163), National Provider Identifier (OPMI_0000503), DEA identifier (OPMI_0000504)
SPECIMEN	6/15	specimen ID (OBI_0001616), date of specimen collection (OBIB_0000714), anatomical structure (UBERON_0000061)
VISIT OCCURRENCE	**26**/17	visit occurrence (OPMI_0000482), visit start date (OPMI_0000487), preceding visit occurrence (OPMI_0000492)
PROCEDURE OCCURRENCE	13/16	procedure (NCIT_C25218), procedure start date (OPMI_0000508), procedure end date (OPMI_0000510)
DRUG EXPOSURE	18/23	drug exposure (OPMI_0000572), drug product (DRON_00000005) drug exposure start time (OPMI_0000565)
CONDITION OCCURRENCE	**38**/16	condition occurrence (OPMI_0000527), medical condition status (OPMI_0000533), admission diagnosis status (OPMI_0000542)
DEVICE EXPOSURE	7/15	device exposure (OPMI_0000554), device (OBI_0000968), device exposure start date (OPMI_0000562)
MEASUREMENT	11/20	clinical measurement identifier (OPMI_0000582), measurement time (OPMI_0000579), measurement unit label (IAO_0000003)
OBSERVATION PERIOD	5/6	observation period start date (OPMI_0000577), observation period end date (OPMI_0000578),

OMOP CDM term mapping by element types

- Many terms not yet covered
- OMOP element types mostly missing:
  - **source concept id**
  - **source value**
- **Examples** of mapping or no mapping:
  - **measurement_concept_id** mapped to ‘clinical measurement’ (CMO_0000000)
  - measurement_**source_concept**_id (no mapping)
  - measurement_**source_value** (no mapping)

types	OMOP terms	OMOP mapped	percent mapped
_type_concept_id	11	11	100.00%
name_id	34	30	88.24%
_date	34	27	79.41%
_concept_id	30	18	60.00%
_concept_name	30	16	53.33%
source_concept_id	17	1	5.88%
_source_value	34	1	2.94%
Total	179	93	51.96%

Table 2

Ontologization of OMOP medical occurrences

- In OMOP, many terms denote events occurring *over a period of time*.
- These defined as BFO:**process** terms
  - medical condition occurrence
  - medical exposure
    - device exposure
    - drug exposure
  - medical procedure occurrence
  - medical visit**
  - (note: red labels OMOP tables)
- All are subclasses of OPMI: medical occurrence.

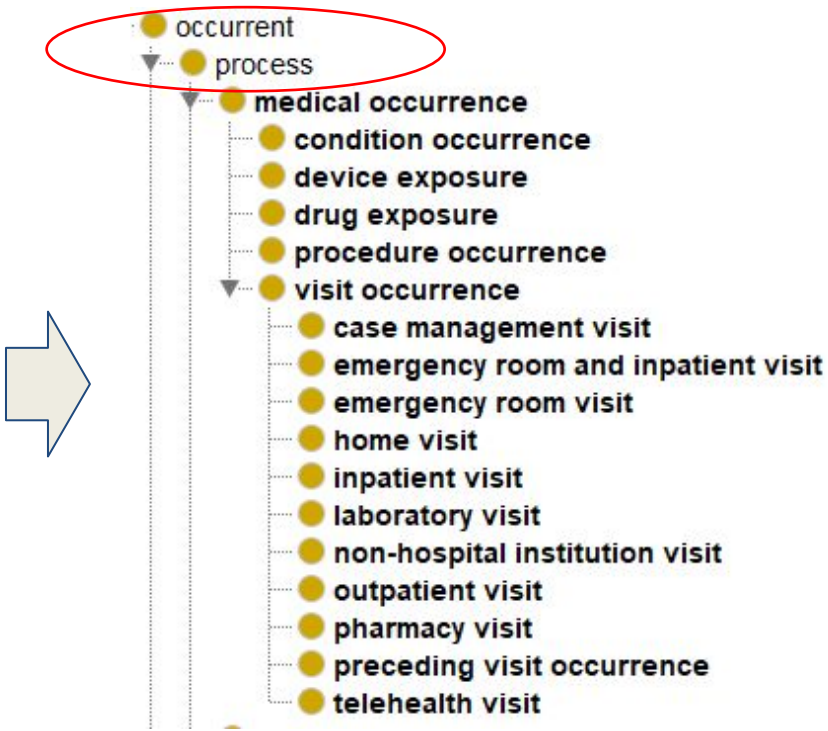


Figure 3

Mapping temporal date/time in OMOP

- Temporal elements in 6 **OMOP** tables: Person, Visit, Device/Drug Exposure, Procedure/Condition Occurrence
- **OPMI representation:**
  - Direct mapping:
    - visit_start_date → 'visit start date' (OPMI)
    - Separate date and time
      - date: which day
      - datetime: day, hours, minutes, …
  - BFO: 'zero (or one)-dimensional temporal region'

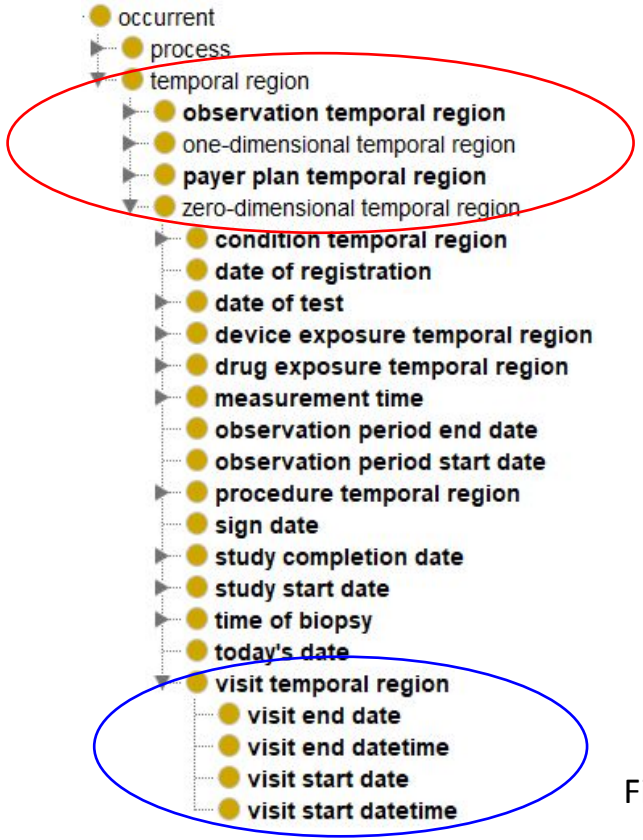


Figure 5

OMOP-2-OPMI Use Case 1:

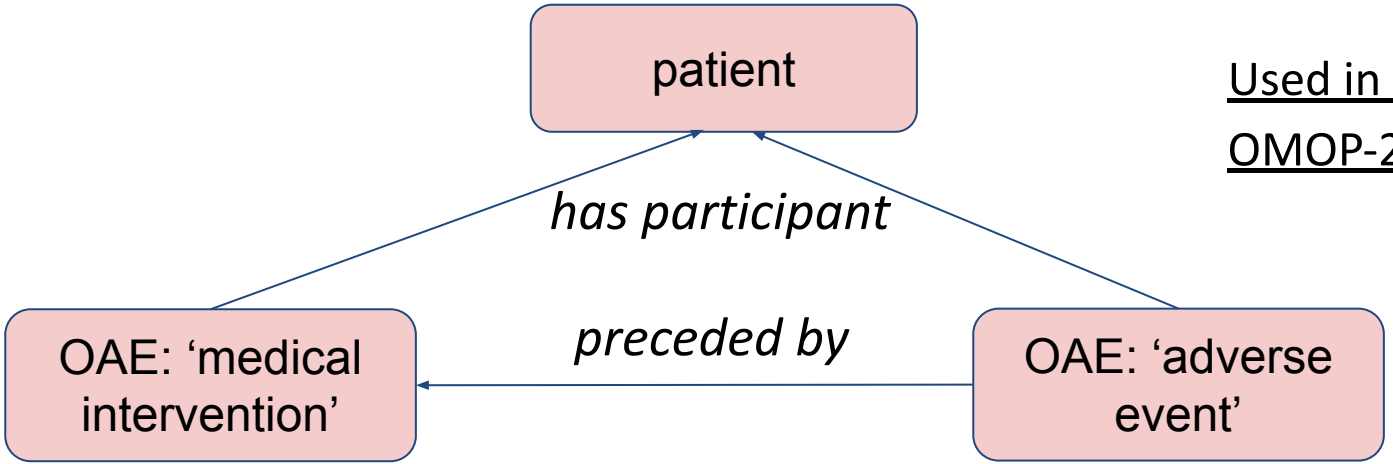
Ontology-level data standardization

- Rooted in the nature of ontology:
  - Standard **representation** & **definitions** of mapped OMOP CDM terms
  - Computer-understandable logic **axioms** among mapped terms
- Furthermore, it's **interoperable** ontology:
  - Also used on other ontologies, e.g., Coronavirus Infectious Disease Ontology
  - Support knowledge/data sharing and integration
- Future: extend to represent other CDMs (e.g., **PCORnet** and **CDISC**) → further support data integration

Use Case 2: Adverse event (AE) modeling & analysis

*OMOP CDM does not have '**adverse event**' (AE) concept.*
however, OMOP-2-OPMI can be semantically extended to model AE

Ontology of Adverse Event (OAE) AE modeling:



Used in OPMI & OMOP-2-OPMI

Example usage of OMOP-2-OPMI modeling:

Modeling of adverse event (AE) using OMOP CDM/data

OMOP-2-OPMI modeling of *adverse event* (AE):

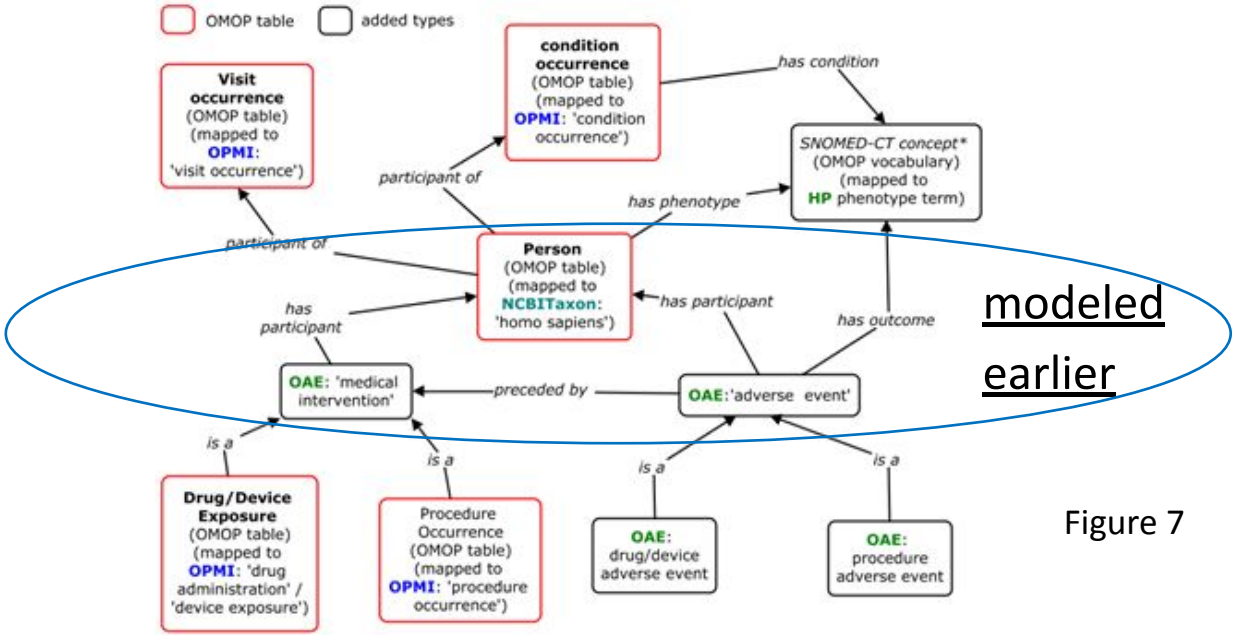


Figure 7

OMOP CDM:

- Do not represent AE directly.

OMOP-2-OPMI modeling:

- Use OAE-based AE modeling (see earlier slide)
- Transfer OMOP CDM data for AE representation, e.g.,
  - **Procedure** is a 'medical intervention'
  - A *new* **condition** afterwards is an AE

Citation: He Y, Ong E, Zheng J, Wan L, Schaub J, Kretzler M. Ontological representation of OMOP CDM using the OBO framework. 2018 OHDSI Symposium, Oct 12, 2018, Bethesda, MD, USA.

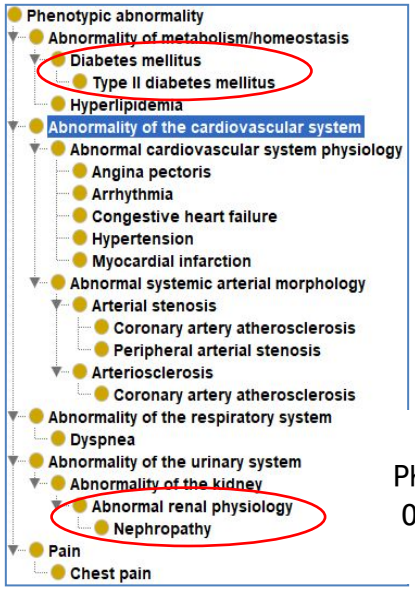
"Heart surgery AKI AE" using OMOP data (from IQVIA)

(*Q: How to detect & find patterns of patients with* Acute Kidney Injury (AKI) AE after heart surgery?)

Algorithm: Define "heart surgery AKI AE" based on OMOP-2-OPMI modeling (earlier slide)

30 days before surgery (no AKI) → **Heart surgery on a patient** → **within 14 days after surgery** (AKI appearance)

Symptoms (Conditions) found at 30 days before heart surgery)



Human Phenotype Ontology (HPO)

Operation on heart (SNOMED: 4275564) and its subclasses

- *15,548* patients in the AKI AE cohort.
- Sex effect:
  - *Male*: 72%;
  - *Female*: 28%
- Age effect:
  - Age > 55: 78.5%

Finding: Phenotypes including **Type II diabetes** & **Nephropathy** are often observed before heart surgery-associated AKI adverse event.

Ref: He et al, ICBO-2019

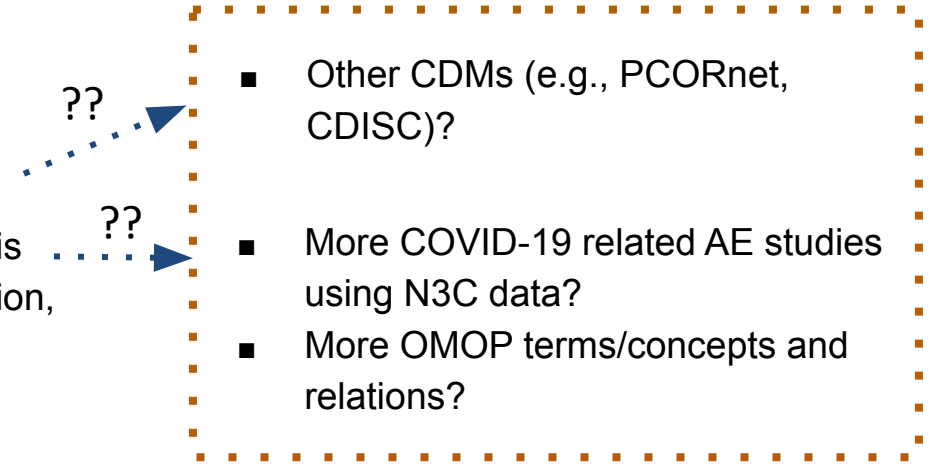
Use Case 3: OMOP-2-OPMI-based COVID-19 clinical data standardization, modeling, and analysis

- National COVID Cohort Collaborative (**N3C**) with >5 mill. COVID cases
  - Analyze **vaccine & drug AEs** using the AE model (earlier slide)
  - **AKI AE** can still be a focus since AKI closely relates to COVID.
  - Effects of **clinical variables** (e.g., age, gender, comorbidities) can be modeled with OMOP-2-OPMI and analyzed using machine learning (**ML**) methods.
- More powerful by co-using the Coronavirus Infectious Disease Ontology (**CIDO**)
  - CIDO represents various COVID-19 knowledge and metadata, e.g., COVID-19 viral variants, vaccines, drugs, etc.

Summary and Discussion

- OMOP **CDM** is an open data standard in observational data integration and analysis
- OPMI is an ontology of precision medicine and investigation
- We further developed OPMI to map OMOP on **CDM** level

- Use cases:
  1. Ontology-level data standardization
  2. Adverse event modeling and analysis
  3. COVID-19 clinical data standardization, modeling, and analysis



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