AIR•MS Training Session III: Multimodal Data

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Icahn School of Medicine at Mount Sinai

Agenda

1) Recap – OMOP and AIR·MS
2) Overview of AIR·MS data
3) Pathology
4) Radiology
5) Mount Sinai Million
6) Cardiovascular Imaging
7) Summary

Recap

What is AIR·MS?

Artificial Intelligence-Ready Mount Sinai (AIR·MS) is a research platform that is composed of:

1) A (very fast) integrated database including Mount Sinai Data Warehouse (MSDW), Pathology and Radiology metadata; and the included data is growing.

2) A Research Environment that allows interactions with the AIR·MS database from Python or R.

3) An Application Tier to host a growing number of applications – including cohort building tools and annotation apps.

https://labs.icahn.mssm.edu/minervalab/air-ms-artificial-intelligence-ready-mount-sinai/

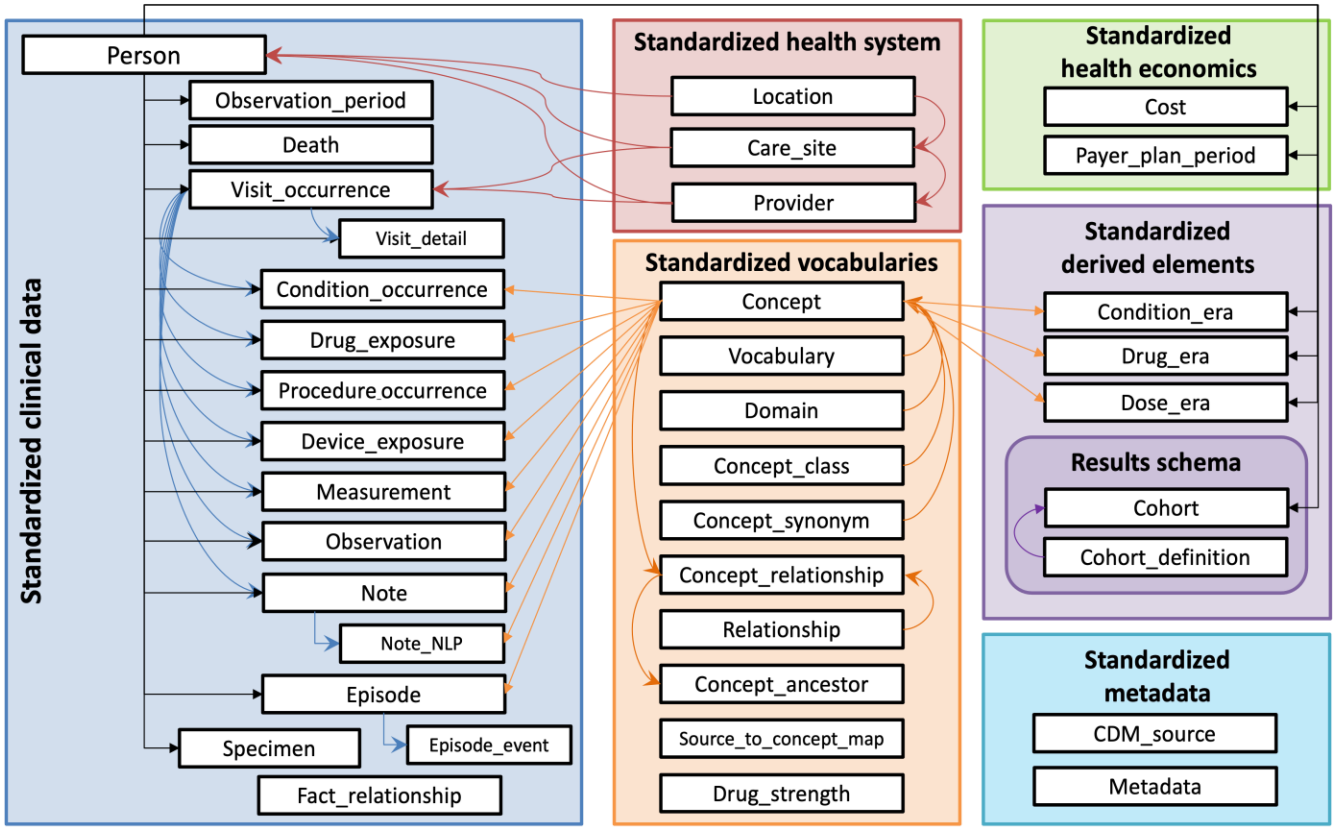
Epic, MSDW, and AIR·MS

Mount Sinai's Epic Electronic Health Record (EHR)

https://labs.icahn.mssm.edu/msdw/

https://labs.icahn.mssm.edu/minervalab/air-ms-artificial-intelligence-ready-mount-sinai/

Main Tables in OMOP Database



Dataset	OMOP Table	# Records
Patients	person	12,051,324 patients
Encounters	visit_occurrence	111,804,681 encounters
Diagnosis	condition_occurrence	120,323,291 diagnoses
Lab Results	measurements	1,107,913,246 results
Medication	drug_exposure	138,120,557 prescriptions
Procedures	procedure_occurrence	326,372,912 procedures
Observations	observation	145,273,185 social histories
Notes	note	204,925,569 notes
Providers	provider	601,032 specialists
Care Sites	care_site	82,103 beds

As of April, 2025

Mapping Concepts and Information

From session 1: we have mapping between the coding systems in Epic and the coding systems used by OMOP:

- We can't just use one giant, static mapping table of Epic codes to OMOP codes because some of the coding systems have commercial licenses.
- Don't just perform keyword searches on codes: sometimes the keywords don't appear, consult an expert clinician.

- (ICD = International Classification of Diseases, SNOMED = Systematized Nomenclature of Medicine, NDC = National Drug Code, ATC = Anatomical Therapeutic Classification, LOINC = Logical Observation Identifiers Names and Codes, CPT = Current Procedural Terminology)

Blue = License / Proprietary Coding

Diagnosis

Epic / ICD-10 → SNOMED-CT

Custom

Drug

NDC, ATC → RxNorm

Athena

Labs

LOINC → LOINC

Procedures

CPT → SNOMED-CT

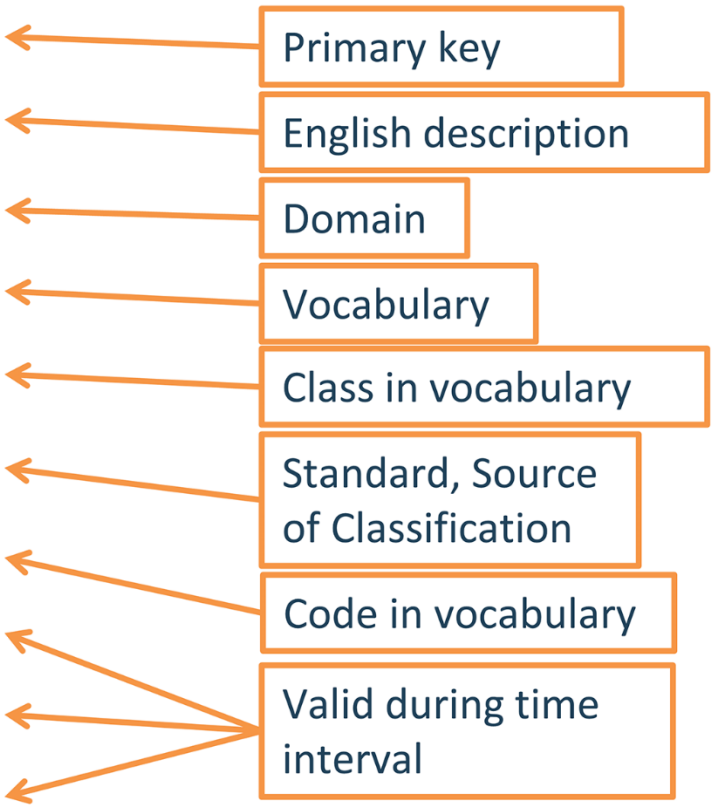
Custom

Using the Data: Querying and Retrieving Data

AIR·MS

- Foundational to OMOP is a “Concept” (stored in the CONCEPT table)
- Concept domains: “Condition,” “Drug,” “Procedure,” “Visit,” “Device,” “Specimen,” etc.

CONCEPT_ID	313217
CONCEPT_NAME	Atrial fibrillation
DOMAIN_ID	Condition
VOCABULARY_ID	SNOMED
CONCEPT_CLASS_ID	Clinical Finding
STANDARD_CONCEPT	S
CONCEPT_CODE	49436004
VALID_START_DATE	01-Jan-1970
VALID_END_DATE	31-Dec-2099
INVALID_REASON	



OMOP Tables

- Have a common naming structure for columns, tables, and can link tables using various IDs

person Column	Description
person_id	Person identifer
gender_concept_id	Gender
race_concept_id	Race
ethnicity_concept_id	Ethnicity
location_id	Location
provider_id	Provider
gender_source_value	(from source)
race_source_value	(from source)
...	

visit_occurrence Column	Description
visit_occurrence_id	ID
person_id	Person ID
visit_start_date	Date
care_site_id	Location
provider_id	Provider
...	

condition_occurrence Column	Description
condition_occurrence_id	ID
person_id	Person ID
condition_concept_id	Concept ID
condition_start_date	Start
condition_end_date	End
stop_reason	Why condition no longer present...
...	

https://www.ohdsi.org/

Patients (`person` Table)

observation		Person	Location		Death	
Patient A	Race	Patient A	Patient A	Home Address A	Patient A	Death date
	Ethnicity					
	Language Preference					
	Sexual Orientation					
Patient B	Race	Patient B	Patient B	Home Address B		
	Marital Status					
	Gender Identity					
Patient C	Ethnicity	Patient C				
	Religious Affiliation					

`person` Column	Description
person_id	Person identifer
gender_concept_id	Gender
race_concept_id	Race
ethnicity_concept_id	Ethnicity
location_id	Location
provider_id	Provider
gender_source_value	(from source)
race_source_value	(from source)
...	

https://www.ohdsi.org/

Overview of AIR-MS Data

Different Datasets Stored in AIR·MS

Currently Available Modalities:

- Mount Sinai Data Warehouse (MSDW), both containing protected health information (PHI) and DeID (deidentified) Observational Medical Outcomes Partnership (OMOP)-mapped electronic health record (EHR)
- Pathology Metadata
- Radiology Metadata
- BioMe/Sinai Million
- Electrocardiogram (EKG)
- Echocardiography

Work in progress: GI Research Database, electroencephalogram (EEG), Endoscopy & Colonoscopy Reports

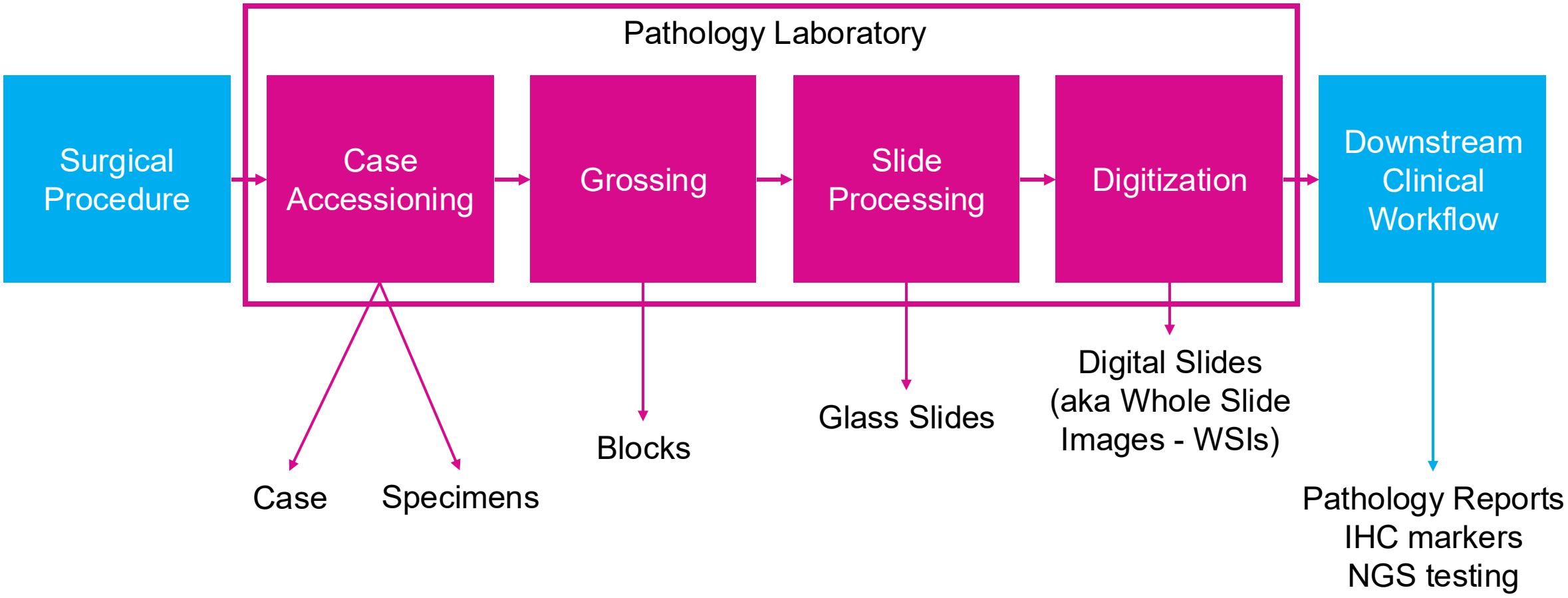
All modalities are stored in separate database schemas, and access is granted to each schema individually based on Institutional Review Board (IRB)

Pathology

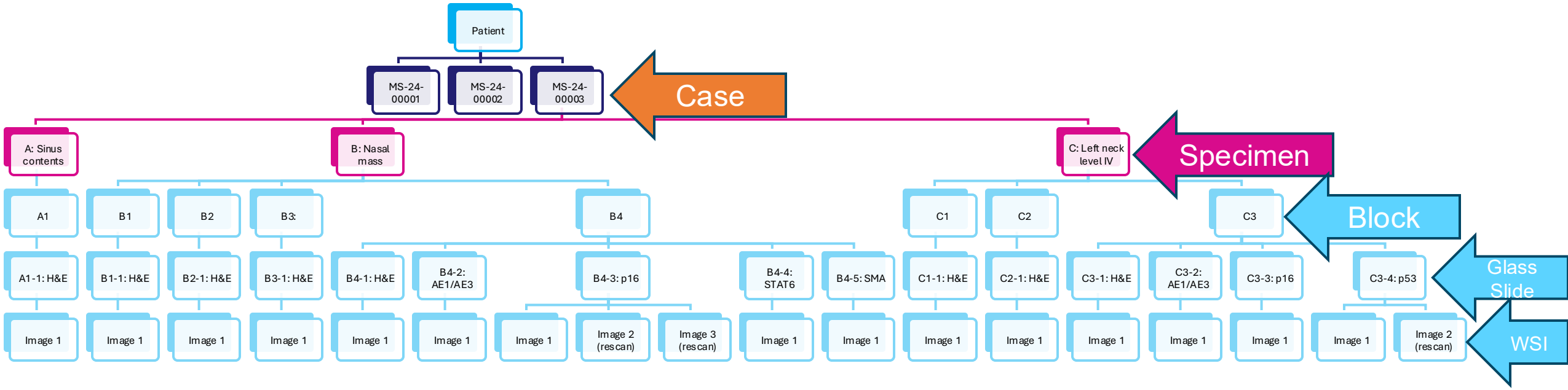
Gabriele Campanella, PhD

Assistant Professor, Artificial Intelligence and Human Health

Pathology Lab Workflow and Data



Pathology Data Hierarchy



Overview of Pathology Data

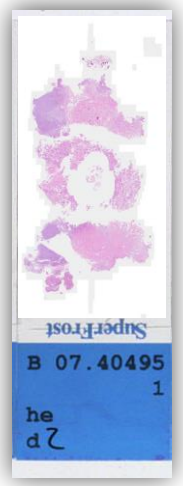
The pathology department produces large amounts of physical and digital data.

Data Modalities

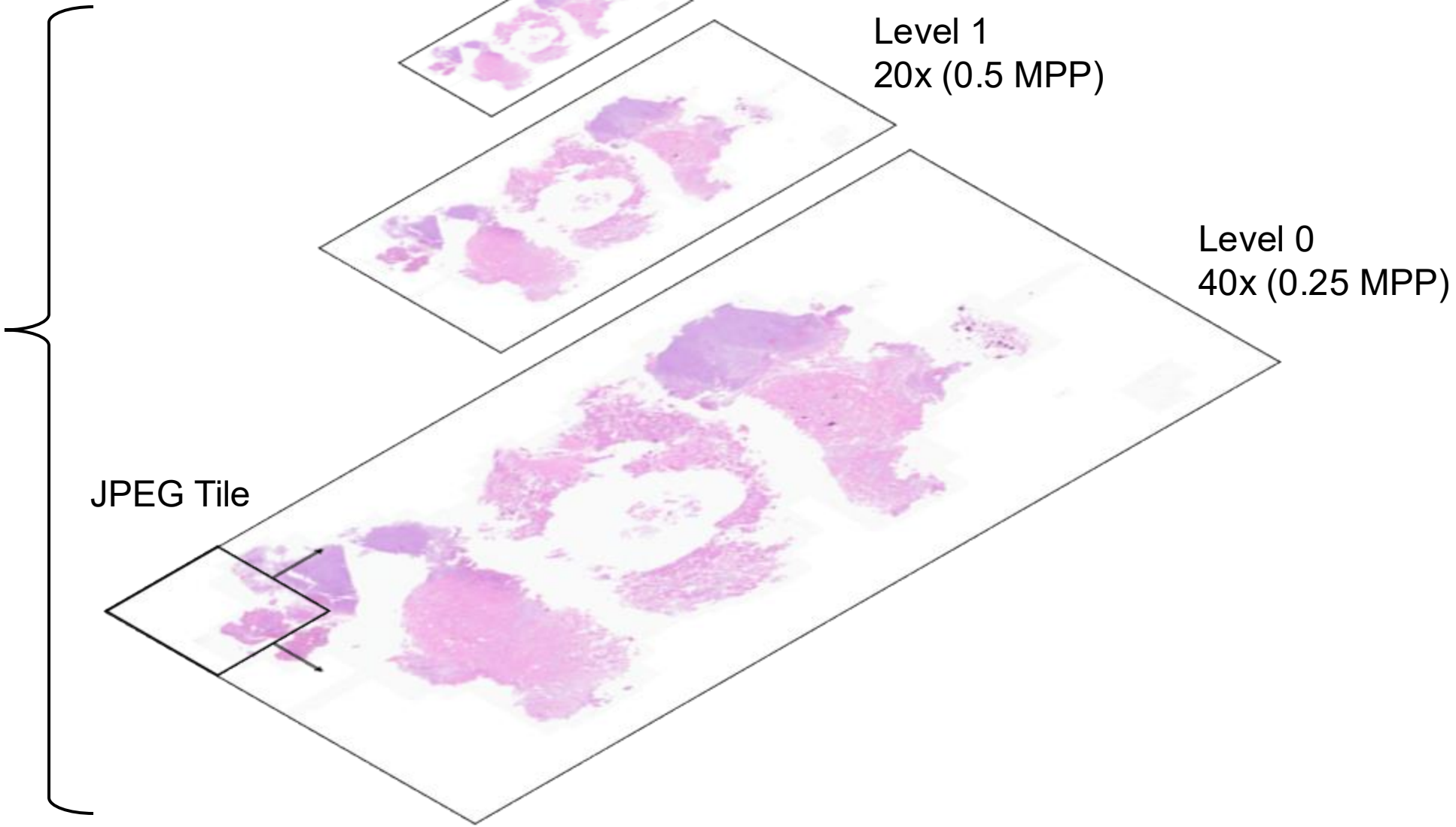
- Biological Assets → Stored for a minimum of 20 years per state regulations
  - Tissue blocks
  - Glass Slides
- Digital Assets
  - Pathology Laboratory Information System (LIS) Metadata → Links cases, specimens, blocks, slides to reports. Tracks most aspects of pathology lab
  - Whole Slide Images → Pyramidal .tiff files scanned with Philips WSI scanners at 40x resolution. Available as part of Data Ark
  - Pathology Reports → Free text diagnosis written by the pathologist for the entire case. Can include test results (IHC, FISH, etc.) as free text.

MPP: microns per pixel

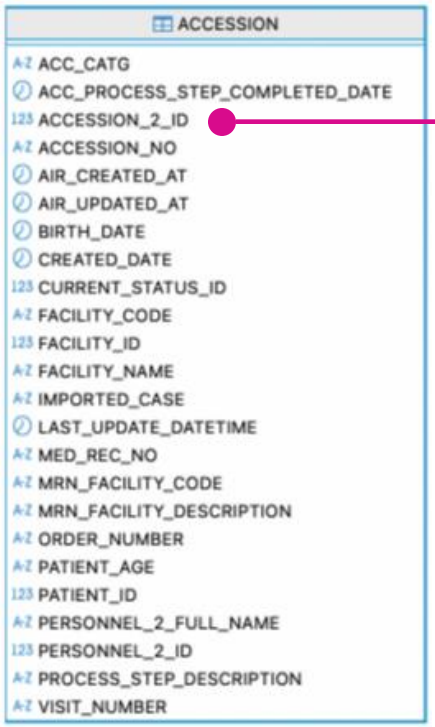
Whole Slide Images



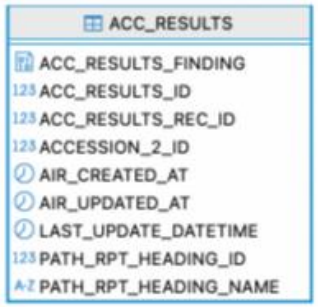
Pyramidal .tiff



Pathology Data in AIR·MS

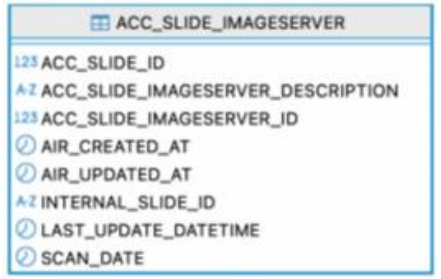


- Pathology case level metadata
- One entry per case



- Pathology report chunks as free text
- Full report is split into sections
  - Specimen Source
  - Grossing
  - Diagnosis
  - Comment
  - Addendum
- One entry per section

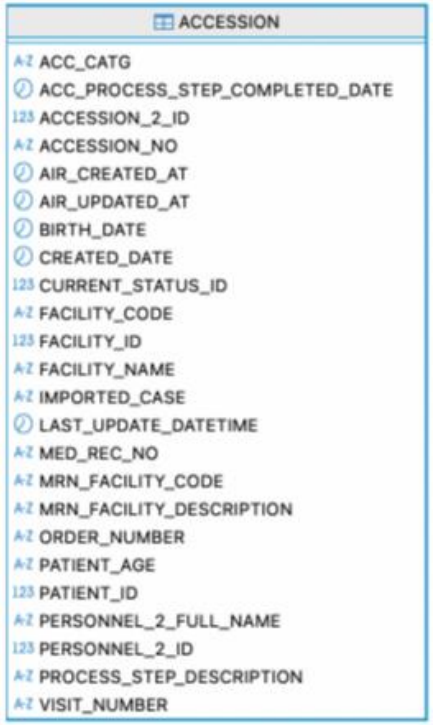
- Glass slide level metadata
- One entry per glass slide



- Digital slide level metadata
- One entry per digital slide

AIRMS Schema: CDMPATHOLOGY

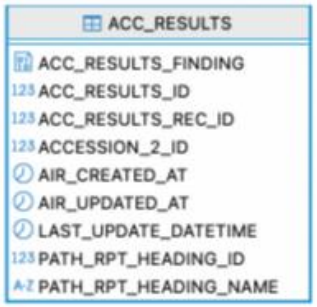
Case Metadata



Frequently used fields:

- *ACCESSION_2_ID* Linking key to other tables.
- *ACCESSION_NO* Accession number, used to identify cases. Pathologist-friendly.
- *MED_REC_NO* EPIC MRN. Can be used to link to other data modalities.

Report Text



Frequently used fields:

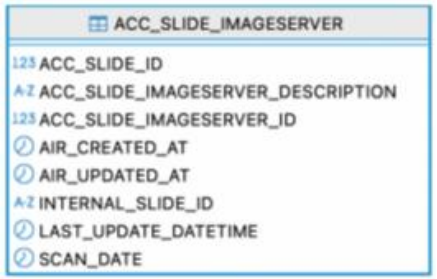
- *ACCESSION_2_ID* Linking key to case table.
- *PATH_RPT_HEADING_NAME* Name of the section. Section naming is not standardized. Some examples:
  - DIAGNOSIS
  - FINAL DIAGNOSIS
  - SPECIMEN SOURCE
  - NOTE
  - ADDENDUM 1, 2, 3, …
  - COMMENT
  - GROSSING
- *ACC_RESULT_FINDING* Actual report text.

Glass Slide Metadata

Frequently used fields:

- *ACCESSION_2_ID* Linking key to case table.
- *ACC_SLIDE_ID* Linking key to other tables.
- *SPECIMEN_LABEL* Specimen identifier within the case. Uppercase letter (A, B, …). Matches specimen labels in free text pathology report. Pathologist-friendly.
- *ACC_BLOCK_LABEL* Block identifier within the specimen. Number (1, 2, …). Matches block labels in free text pathology report, usually in the grossing description. Pathologist-friendly.
- *SLIDE_LABEL* Slide identifier within the block. Number (1, 2, …). Not used in free text reports usually. Pathologist-friendly.
- *RECV_DATE* Received date of the specimen. Useful to match cases to other data modalities.
- *LAB_PROCEDURE_DESCRIPTION* Lab order that generated the slide. Usually a stain name. For example: H&E, PDL1, ER, PR, …

Digital Slide Metadata



Frequently used fields:

- *ACC_SLIDE_ID* Linking key to slide table.
- *INTERNAL_SLIDE_ID* 6-char alphanumeric code that uniquely identifies a glass slide. Not pathologist-friendly. Aka BARCODE. If a barcode exists, the slide was scanned.
- *ACC_SLIDE_IMAGESERVER_DESCRIPTION* long alphanumeric code that uniquely identifies a .tiff file. Unique to a scanning event, not to a glass slide. Same barcode can be associated to multiple .tiff files (e.g., rescanning). Not pathologist-friendly.
- *SCAN_DATE* Timestamp of scanning event.

NOTE:

- Scanning started in 2020 at 40% capacity. 100% prospective digitization was reached in 2024. Most slides are still not scanned.
- *INTERNAL_SLIDE_ID* and *ACC_SLIDE_IMAGESERVER_DESCRIPTION* can be used to identify slides in Data Ark. Mapping is not publicly available.

Pathology Metadata – Practical Tips

- **How to communicate with the pathologist**
  Accession numbers, specimen/block/slide labels are well understood by pathologists.
  For example: slide “A1-1” from block “A1” in case MS-24-00001.
- **Linking slides to a diagnosis is challenging**
  Reports are written for the entire case. Most granular diagnosis is at the specimen level (unstructured). There is no slide level description. It is important to talk to a pathologist to understand which slides from a case/specimen are relevant to your study.
- **Some metadata can be inaccurate**
  Some metadata fields exposed are used internally in the pathology department for workflow management. They are not for diagnostic purposes and can be inaccurate. Examples include: division, organ, specimen description, ICD codes. Always talk to a pathologist to discuss how to best approach your problem.
- **Data Ark slide links are not publicly available**
  To obtain Minerva paths to a set of slides can be done through MSDW (requires IRB). You will need *INTERNAL_SLIDE_ID* and *ACC_SLIDE_IMAGESERVER_DESCRIPTION* for each slide in your cohort.

Radiology

Francesco La Rosa, PhD

Instructor, Artificial Intelligence and Human Health

Overview of Radiology data

What type of data is it, and where is it produced?

- Medical imaging data (e.g., MRI, CT, X-ray) produced by radiology scanners and associated acquisition systems. During routine clinical care it is acquired for diagnosis and treatment planning.

Where is it stored?

- In PACS for clinical use, in XNAT for research studies.

What data standards exist?

- DICOM: how medical images and associated metadata are formatted, stored, and annotated across systems. It ensures interoperability between scanners, PACS, and analysis tools by specifying image encoding, patient/study identifiers, acquisition parameters, and standardized metadata tags.
- DICOM tags: identify the attribute, usually in the format (XXXX,XXXX) with hexadecimal numbers. The first group represents the DICOM group number, and the second represents the element number. Together, they uniquely define each tag. For example, (0008,0060) for Modality or (0010,0010) for Patient Name.
- DICOM tag explorer: https://www.dicomlibrary.com/dicom/dicom-tags/

Radiology Metadata on AIR·MS

Schema and Access

- Stored within the CDMRADIOLOGY schema in AIR·MS.
- Access requires: IRB approval and project registration. Can be request in SailPoint.

Tables and Content

- Two tables with several attributes available on AIR·MS

RADIOLOGY_METADATA
ID
PATIENT_ID
SERIES_INSTANCE_UID
STUDY_INSTANCE_UID
ETL_RECORD_UPDATE_DATETIME

RADIOLOGY_DICOM_DATA
ID
RADIOLOGY_METADATA_ID
AG_VALUE_REPRESENTATION
DICOM_TAGS
SERIES_INSTANCE_UID
STUDY_INSTANCE_UID
TAG_XTN_PATIENT_EPIC_MRN

Radiology Metadata on AIR·MS

Linkage to EHR Cohorts

- The RADIOLOGY_METADATA PATIENT_ID correspond to the MRN codes and can be linked with OMOP EHR dataset in AIRMS.

Raw Data Storage

- The imaging data is stored in PACS
- It can be requested from the Mount Sinai Imaging Warehouse

Radiology Metadata - Pitfalls and Dangers

Common mistakes by non-experts

- One study (STUDY_INSTANCE_UID) can contain many SERIES_INSTANCE_UIDs (each corresponding to a different sequence, acquisition, or reconstruction).

Other important aspects

- The DICOM tags values are not always consistent, so they should always be verified and standardized before analysis.

Radiology Metadata Use Case

Hypothetical use case:

- Identify all adults diagnosed with spondylolisthesis who subsequently underwent fusion surgery and had at least one pre- or post-operative imaging study.

Data sources and Linkage strategy

- OMOP tables PERSON, CONDITION_OCCURRENCE, PROCEDURE_OCCURRENCE, and CONCEPT_ANCESTOR to identify spondylolisthesis and fusion events
- Linked to imaging data in CDMRADIOLOGY.RADIOLOGY_METADATA and CDMRADIOLOGY.RADIOLOGY_DICOM_DATA via MRN (PATIENT_ID) and metadata IDs
- Filtered for MRI lumbar studies using DICOM Modality and Body Part Examined tags.

Mount Sinai Million/BioMe Biobank

Michael Preuss, PhD

Assistant Professor, Artificial Intelligence and Human Health

Overview of Mount Sinai Million Health Discoveries Program

What type of data is it?

- Meta data, sample IDs for the Mount Sinai Million Health Cohort (Bio*Me* Biobank, MSM Biobank)
  - MRNs (PHI data) &
  - De-id MRNs

  → Same sample for actual genetic data, MSM Biobank (Bio*Me* Biobank) on Minerva

Where is it stored?

- The genetic data is stored on Minerva HPC in /sc/arion/projects/MSM

Access via registration Data and Specimen form

What data standards exist, (only Minerva)?

- Imputation (bgen format) & WES data VCF format
- Single sample gVCF
- PhecodeX tables
- Annotated data (VEP, including LOFTEE and dbNSFP)
- Covariate file with genetic principal components, genetic ancestry, batch covariates, age and sex
- Bulk datasets with QC metrics and CRAM files

Mount Sinai Million / BioMe on AIR·MS (PHI / de-id) 1/2

Schema and Access

Stored within the schema

- CDMMSM (PHI, MRN)
- CDMMSMDEID (de-id)

Access requires:

- IRB approval (only CDMMSM) in SailPoint Mount Sinai Million / BioMe identifiable **&**
- (optional) project registration Data and Specimen form for actual genetic data access on Minerva

Linkage to EHR Cohorts

- Linkage is performed via the Medical Record Number (MRN):
  - `XTN_PATIENT_EPIC_MRN` in the PERSON table of the MSDW OMOP schema (CDMPHI)
  - `MRN` in the PATIENT table of the MSM Biobank schema (CDMMSM)

Raw data storage

- On Minerva `/sc/arion/projects/MSM`

Mount Sinai Million / BioMe on AIR·MS (PHI / de-id) 2/2

Tables and Content

Mount Sinai Million / BioMe identifiable (PHI) *

Schema: CDMMSM Data •
snapshot from 06/09/2025 •
Unique patients: 279,885

*Schema: CDMMSMDEID (DE-ID)
same but without MRN

PATIENT	Comments
ID	Internal ID for linking to other tables within the dataset
MRN	Medical Record Number (EPIC MRN - only accessible under regulatory approval)
MASKED_MRN	De-Identifier for combined Bio*Me* Biobank set with Regeneron and Sema4 data
RGN_ID	De-identifier for first Regeneron batch regarding Bio*Me* Biobank
SEMA4_ID	De-identifier for Sema4, a subset of Masked MRN ID
MSM_ID	De-identifier for Mount Sinai Million Biobank, a combined setoff RGN_ID and new MSM ID
MILLION_ID	Indicator for **all consented**patients with and without genomic data
AIR_CREATED_AT	Record creation in AIR·MS
AIR_UPDATED_AT	Record updated in AIR·MS

Medical Record Number (PHI) serves to cross Reference with OMOP and other data modalities

Only of importance when
you were working with BioMe Biobank and
And want to cross reference MSM Biobank

MSM de-id for the Mount Sinai Million Biobank cohort, sample identifier (patient was genotyped)

Just an indicator ID, its presence shows that the patient was consented by the MSM protocol
(the patient can be genotyped or not (yet))

Pitfalls and Dangers

Common mistakes by non-experts

- What are the typical errors you see when people new to this data modality start working with it?
- Examples: misinterpretation of variables, misuse of identifiers, incorrect assumptions about completeness.

Other important aspects

- What should users keep in mind when analyzing or linking this modality?
- Are there modality-specific caveats (e.g. unit conversions, coding systems)?

General pitfalls

- What traps do people often fall into that could compromise data quality, analysis, or interpretation?

CDMMSM Use Case

Hypothetical use case:

“Identify Mount Sinai Million participants with a hypertension diagnosis (ancestor concept 320128), returning their earliest diagnosis date along with Person ID and MRN, restricted to consented individuals present in CDMMSM.PATIENT.”

Data sources and linkage strategy:

OMOP tables: person, condition_occurrence, measurement (for blood pressure), procedure_occurrence (for treatment codes).

Biobank tables: CDMMSM.PATIENT (MSM_ID, MRN, consent indicators).

Linkage identifier: EPIC Medical Record Number (XTN_PATIENT_EPIC_MRN ↔ MRN).

Strategy: Restrict to consented MSM participants; subset to those with non-null MSM_ID (genetic data available).

Sample Query

- Extracts patients with a hypertension diagnosis (using OMOP ancestor concept 320128), returning their earliest diagnosis date (DX_DATE), Person ID, and MRN.
- Only includes patients who are part of the Mount Sinai Million (consented cohort), identified by the presence of their MRN in CDMMSM.PATIENT.

```
SELECT
    MIN(co.condition_start_date) AS dx_date,
    co.person_id,
     pe.xtn_patient_epic_mrn AS mrn
 FROM CDMPHI.condition_occurrence AS co
 JOIN CDMPHI.concept_ancestor AS ca
   ON ca.descendant_concept_id = co.condition_concept_id
 JOIN CDMPHI.person AS pe
   ON pe.person_id = co.person_id
 JOIN CDMMSM.patient AS p
   ON p.mrn = pe.xtn_patient_epic_mrn
 WHERE ca.ancestor_concept_id = 320128
 AND pe.xtn_patient_epic_mrn IS NOT NULL
 GROUP BY
   co.person_id,
   pe.xtn_patient_epic_mrn
```

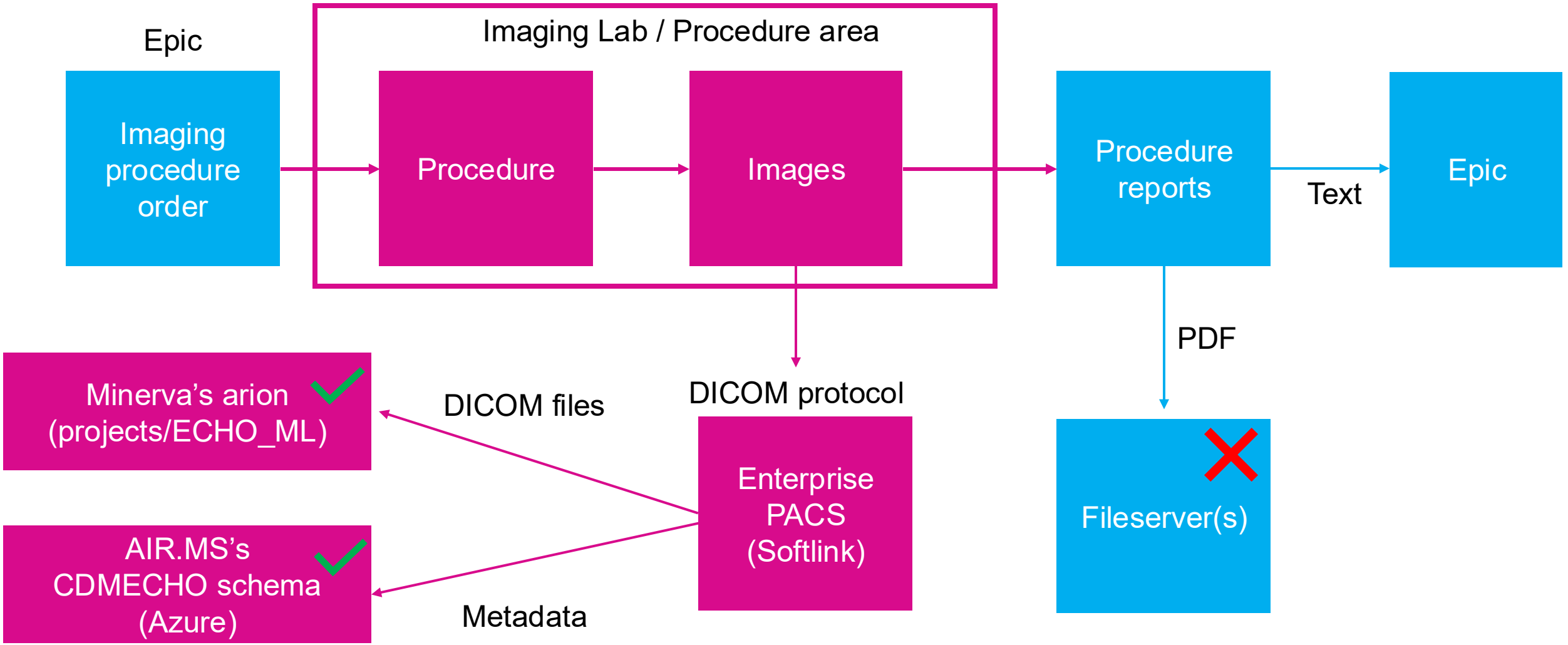
NB: can substitute 261326 with any other standard OMOP concept to change the query for another disorder (and including all child concepts). Find standard concepts here

Cardiovascular Imaging

Ashwin Sawant, MD

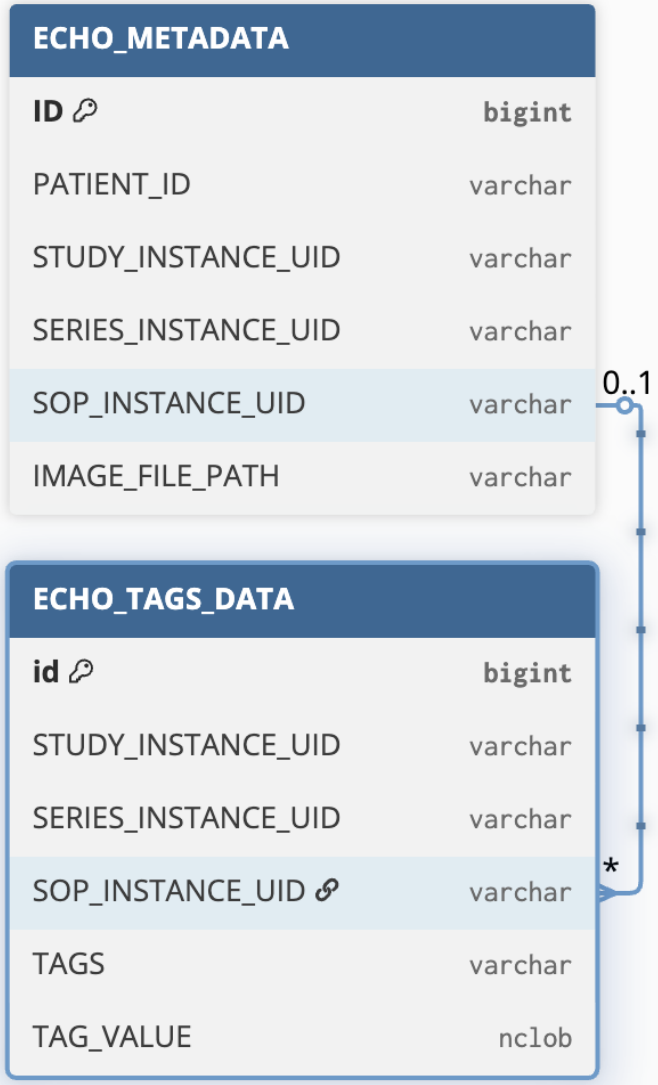
Artificial Intelligence and Human Health

Overview of cardiovascular imaging



Types of imaging studies

- Echocardiograms
- Coronary artery catheterization
- Transcatheter aortic valve replacement
- Peripheral vascular procedures
- We also found some CT, MRIs but haven’t explored them



Tags of interest:

1. PatientID: MRN

2. StudyDate, StudyTime

3. Modality:
    1. XA = x-ray angiography (cardiac catheterization, peripheral vascular catheterization)
    2. US = ultrasound (echocardiography)

4. IMAGE_FILE_PATH:
   `/sc/arion/projects/ECHO_ML/softlink_archive/…`

SAMPLE QUERY 1

Use case: find all cardiac catheterization studies done in 2022

```
SELECT DISTINCT p.PERSON_ID, emd.PATIENT_ID, TO_CHAR(etd.TAG_VALUE) AS "StudyDate",
                emd.STUDY_INSTANCE_UID, emd.SERIES_INSTANCE_UID, emd.IMAGE_FILE_PATH
    FROM CDMPHI.PROCEDURE_OCCURRENCE po
        JOIN CDMPHI.PERSON p ON po.PERSON_ID = p.PERSON_ID
        JOIN CDMECHO.ECHO_METADATA emd ON p.XTN_PATIENT_EPIC_MRN = emd.PATIENT_ID
        JOIN CDMECHO.ECHO_TAGS_DATA etd ON emd.SOP_INSTANCE_UID = etd.SOP_INSTANCE_UID
    WHERE po.PROCEDURE_SOURCE_VALUE = 'CARDIAC CATH (CVI)'
        AND etd.TAGS = 'StudyDate'
        AND TO_CHAR(etd.TAG_VALUE) BETWEEN '20220101' and '20221231';
```

LOADING DICOM IMAGES

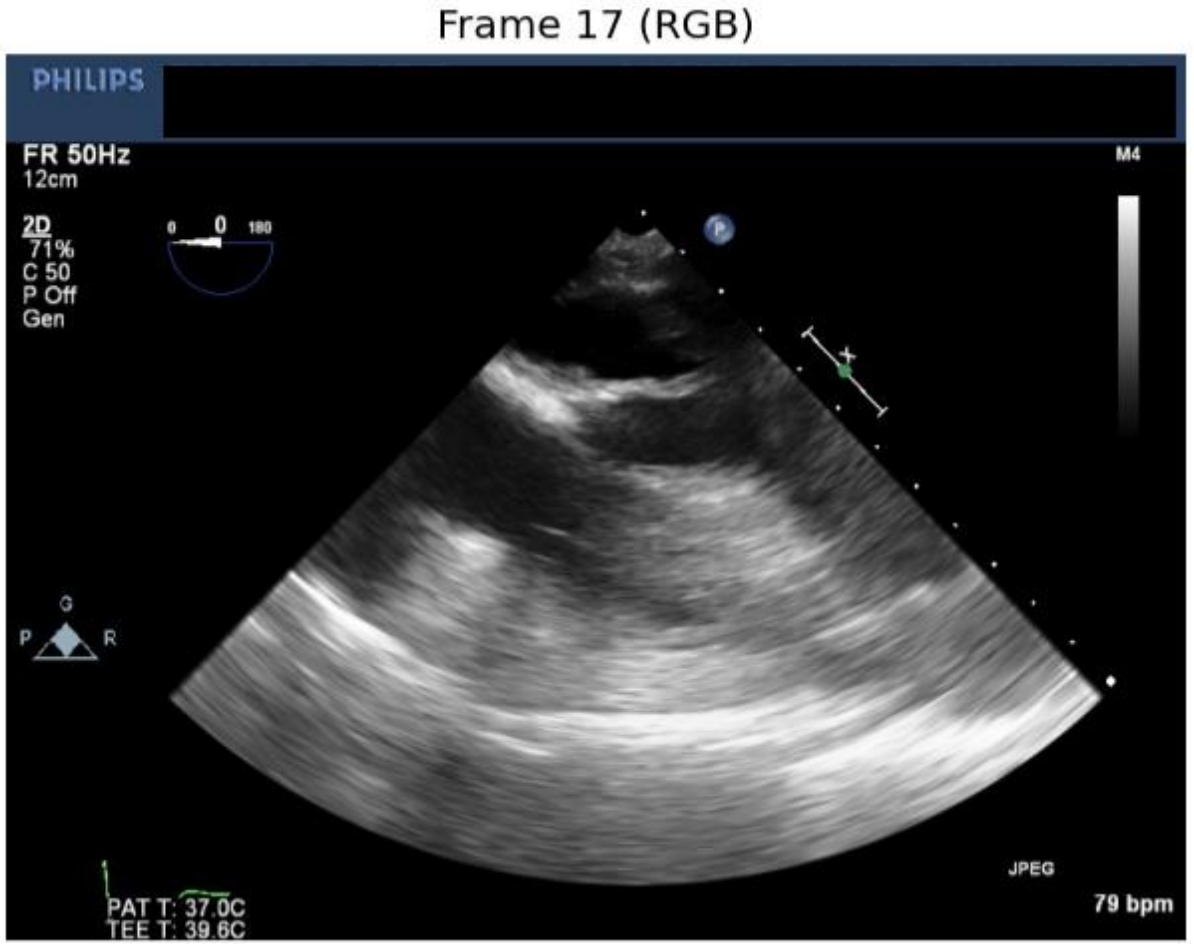
Example: read a DICOM file from an echocardiogram series, and display a frame in a notebook.

```python
import pydicom
import matplotlib.pyplot as plt

ds = pydicom.dcmread("filename")
arr = ds.pixel_array

# pick a frame to show
frame_idx = arr.shape[0] // 2
frame = arr[frame_idx]

plt.figure(dpi=120)
plt.imshow(frame)
plt.title(f"Frame {frame_idx} (RGB)")
plt.axis("off")
plt.show()
```



Accessing the data

- PHI dataset – needs IRB approval
- For now, reach out to AIR·MS team
- Sailpoint workflow is under development

CDMECHO - Pitfalls and Dangers

- Link to EHR data is in progress
- Duplicate studies
- PatientIDs don’t match Epic MRNs in older files
- The underlying EHR -> PACS link is based on MRN + study date (not even study time)

Summary

Summary & Conclusions

- AIR·MS represents a valuable, integrated dataset accessible through SQL.
- We are investigating additional datasets over the coming months.
- As AIR·MS matures, an app layer will be built out where reusable machine-learning pipelines can be implemented on clinical data.
- Building an ecosystem to accelerate clinical research and discovery, and we appreciate your input!