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Documentation of the ontology of the IRDBB semantic repository

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1. Introduction

This document provides a documentation of the ontology of the semantic repository of the Image and Radiation Dose BioBank (IRDBB). This ontology was initially developed in 2017 to cover the needs expressed by the MEDIRAD partners in their answers to the questionnaire sent on October 5th, 2017 (User needs concerning the IRDBB repository). It was then refined between 2017 and 2020.

History of versions

Version	Date	Description
V1.0	30/11/2017	Preliminary version

V1.1	31/3/2018	First consolidated version
		Main changes:
		• Importation of annotations from the DICOM DCM content mapping resource
		• Coverage of the following DICOM Context Groups (used by the templates falling into the scope of MEDIRAD)
		  ○ CID 225 Measurement Uncertainty Concepts
		  ○ CID 10000 Scope of Accumulation
		  ○ CID 10006 X-Ray Filter Materials
		  ○ CID 10007 X-Ray Filter Types
		  ○ CID 10011 Effective Dose Evaluation Method
		  ○ CID 10013 CT Acquisition Type
		  ○ CID 10021 Source of CT Dose Information
		  ○ CID 10023 Size Specific Dose Estimation Method for CT
		  ○ CID 10033 CT Reconstruction Algorithm
		  ○ CID 10034 Reason for Repeating Acquisition
		  ○ CID 10044 Radiosensitive Organs
		  ○ CID 10045 Radiopharmaceutical Patient State
		  ○ CID 10061 Absorbed Radiation Dose Types
		  ○ CID 10062 Equivalent Radiation Dose Types
		  ○ CID 10063 Radiation Dose Estimate Distribution Representation
		  ○ CID 10064 Patient Model Type
		  ○ CID 10065 Radiation Transport Model Type
		  ○ CID 10066 Attenuator Category
		  ○ CID 10067 Radiation Attenuator Materials
		  ○ CID 10068 Estimate Method Types
		  ○ CID 10069 Radiation Dose Estimation Parameter
		  ○ CID 10070 Radiation Dose Types
		• Extensions for covering the needs of WP3 (subtask 3.2 and 3.3)
		• Addition of annotations (skos:prefLabel, IAO:definition, skos:note)

V1.2	4/05/2018	Second consolidated version Main changes: • Addition of entities (classes, object properties and data properties) corresponding to the WP2 and WP3 needs • Cleaning of the FMA extract (removal of axioms) and addition of anatomical structures needed by OLINDA
V1.3	31/12/2020	Final version Main changes:

		• New addition of entities (classes, object properties and data properties) corresponding to the WP2 and WP3 needs • Sparklis module • Detailed history provided in Annex 2

2. Methodology

2.1. Definition of the scope

The scope of this ontology was defined from the answers received to the questionnaire sent to the MEDIRAD partners on October 5th, 2017. Basically, these answers highlighted the importance of the various DICOM Dose Structured Reports, and suggested that most of the data items that they contain should be represented in the semantic repository. So, this first version of the ontology primarily relies on the specification of the contents of the existing DICOM Dose report Information Object Definitions (IODs). It is assumed that most of entities to be used in the IRDBB semantic repository actually appear in the DICOM Dose reports, which justifies to start with these terms.

The first aspect of the work was a preliminary identification of the relevant entities from the relevant templates available in DICOM Part 16. These templates have a hierarchical structure described in Annex 1. The list of the Root templates corresponding to the three main DICOM Dose Reports that we have considered is given in Table 1.

Template ID	Root template
TID 10011	CT Radiation Dose SR IOD Templates
TID 10021	Radiopharmaceutical Radiation Dose
TID 10030	Patient Radiation Dose

Table 1. List of DICOM Dose SR IOD Root templates

This analysis led to the design of a UML class diagram, showing both the main involved entities and the basic relationships connecting them. The latter are important because they will help specifying 1) the essential properties to be modelled in the axioms associated to each class, and 2) that will ultimately connect the instances in the IRDBB semantic repository.

Besides the templates, it was also necessary to consider in detail the DICOM Content Mapping Resource (DCMR) Context Groups that are referred in the templates, because they list the actual coded values that will be found in the actual DICOM reports SOP instances to be managed in the IRDBB repository. For example, the list of Radiosensitive Organs is provided in CID 10044.

2.2. Alignment with, and reuse of existing ontologies

The second aspect of the work consisted in searching in the ontology literature and in the existing ontology repositories (NCBO Bioportal, Ontobee repository) what ontological resources could be reused. As a general strategy, it was decided to use the Basic Formal Ontology (BFO) as a foundational ontology, and to rely as much as possible on the ontologies available from the Open Biomedical Ontologies (OBO) foundry. The list of the ontologies considered to be reused is provided in Table 2.

Acronym	Name	Entirety or extract
BFO2	Basic Formal Ontology	entirety
OBI	Ontology of Biomedical Investigations	extract
IAO	Ontology of Information Artefacts	extract
FMA	Foundational Model of Anatomy	extract
UO	Ontology of Units (of Measurements)	extract
PATO	Ontology of qualities (phenotypic traits)	extract
SNMI	Ontology of radiopharmaceuticals (SNMI)	extract
CheBI	Ontology of radionuclide_CheBI	extract

Table 2. List of reused ontologies

Concretely, this led to associating to each important entity of the previous class diagram either a corresponding term from an existing ontology, or a term that provides a superclass of this entity, which will be given an identifier (IRI) in the MEDIRAD ontology.

When multiple terms need to be extracted from the same ontological source, this extraction needs to be automated. Based on our experience, we used the OntoFox software [1,2] based on the MIREOT method [3], that allows to tune and to achieve such extraction. This software allows to specify precisely what items should be extracted (e.g. parent classes, subclasses, associated axioms and annotation properties). It produces an OWL file that constitutes a module of the ontology (to be imported by the application ontology).

2.3. Modelling of entities

Of course, only a limited number of terms could be found in existing ontologies. For the other terms, we had to model the corresponding entities, in conformance with BFO. As a general modelling approach, we relied on the "realism-based" principle, consisting in focusing attention on the entities that exist in reality, rather than abstractions, as recommended in the OBO foundry community. This consists is making very clear distinctions between, e.g. irradiated entities (e.g. a physical person), the processes that cause irradiation (e.g. a CT examination, injection of a radiopharmaceutical), and information about such entities (e.g. a DICOM dose structured report, a CT Dose Index $_{vol}$ or Dose x Length Product value). Concerning the record of quantitative values, we introduce distinctions between measurement values (that result from some measurement or estimation process), device settings (i.e. elements of an acquisition protocol consisting on setting some parameter to a value) and device characteristics (i.e. elements of specification a device component, e.g. nominal collimation width). This approach allows ignoring many entities in DICOM templates that do not have any counterpart in reality, but are only containers of information, e.g. Observer Context, CT Irradiation Event Data, CT Dose Check Details, Radiopharmaceutical Administration Patient Characteristics, etc.

3. Result

3.1 General organization

The ontology is organized as a set of files represented in OWL, the Web Ontology Language (Fig. 1). Basically, the ontology is essentially a taxonomy of classes, related by the `rdfs:subClassOf` object property (Fig. 2).

As a general rule, the annotation properties associated to entities retrieved from existing ontologies using OntoFox were kept. Concerning the entities that we created, they are contained in the `ontoMedirad.owl` ontology module.

For example, we had to create entities for anatomical entities and units of measurement, and we decided to put them in ontoMedirad.owl module, rather than `FMA_for_OntoMEDIRAD.owl` and `UO_for_OntoMEDIRAD.owl`. The reason for doing that is to be able to easily re-generate the OntoFox extracts without considering any additions.

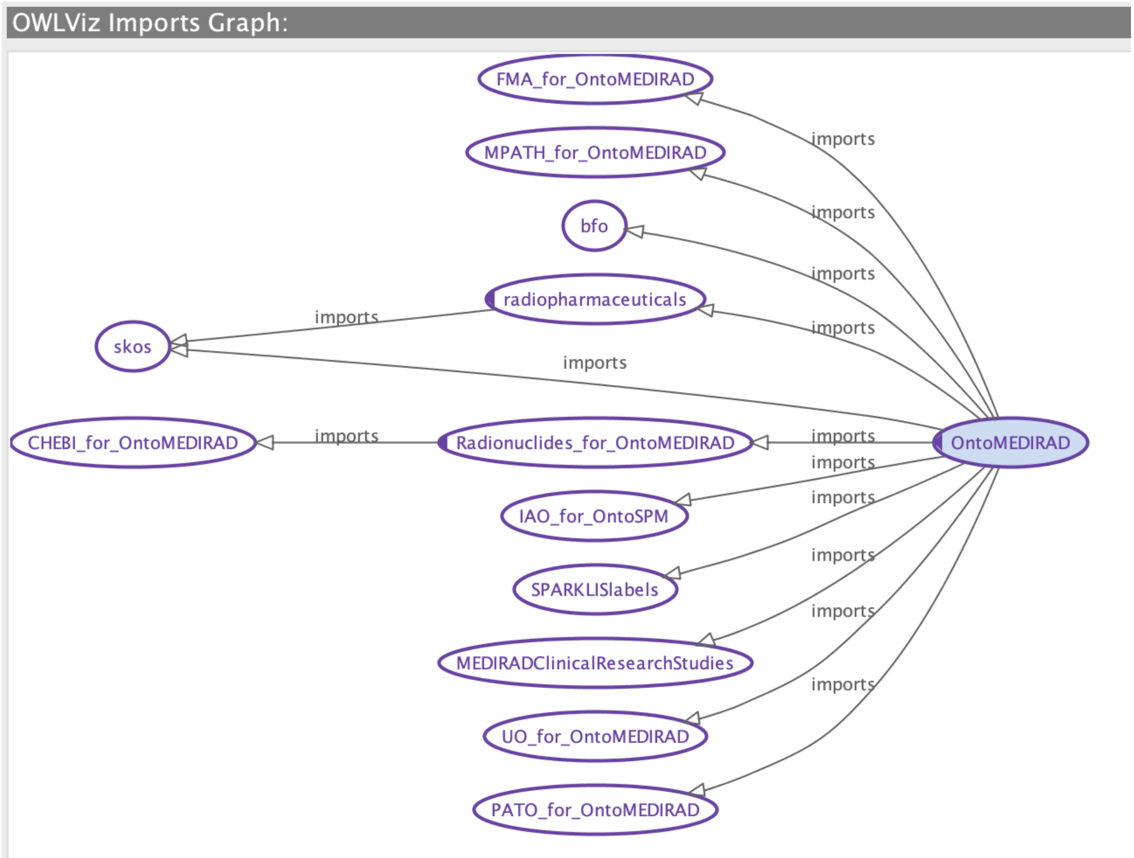


Figure 1: Ontologies imported by OntoMEDIRAD

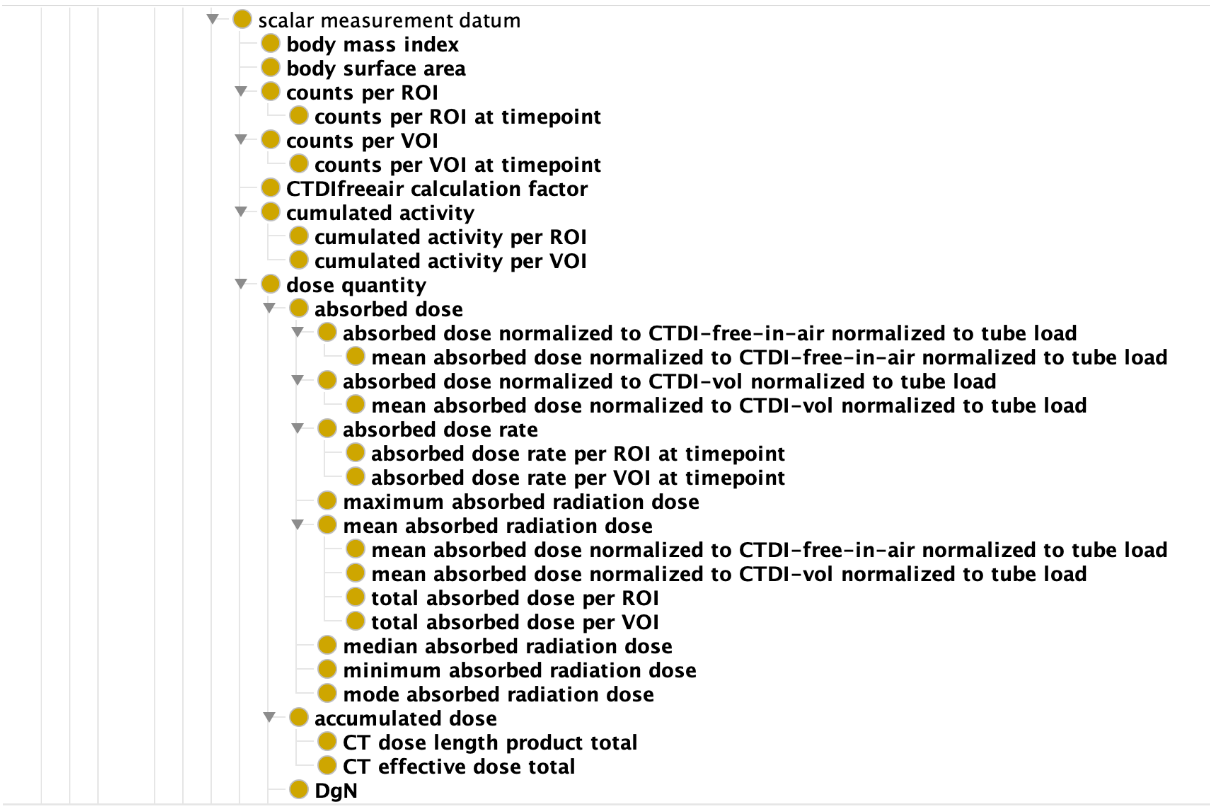


Figure 2: extract of the OntoMEDIRAD taxonomy of classes

3.2 Annotation properties

As a general rule, the labels are provided in the `skos:prefLabel` annotation property.

The definitions are provided in the `purl:IAO_0000115` annotation property (definition).

3.3 Formal axioms

We adopted a rather conservative approach, consisting in limiting the formal axioms associated to each entity. This strategy was motivated by the desire to guarantee reasonable response time when querying in SPARQL the Stardog triple store.

Concretely, the following principles were applied. For classes:

- using the subsumption relation (`rdfs:subClassOf`) for building the basic taxonomy, but trying to limit multiple inheritance as much as possible
- using the property restrictions `owl:someValuesFrom` and `owl:allValuesFrom` when absolutely required to denote the essential characteristics of a Class
- avoiding using the `owl:disjointWith` constructor

For properties:

- using the subsumption relation (`rdfs:subPropertyOf`) as much as possible
- specifying inverse properties as much as possible (`owl:inverseOf`)
- not systematically specifying the `rdfs:domain` and `rdfs:range` of the properties
- not systematically specifying the properties such as transitivity, that may cause difficulties

3.4 DICOM-related terms

Concerning DICOM, we relied on the entities considered in the DICOM terminology (Part 16). They have various origins, primarily SNOMED CT, but also the DICOM DCM terminology resource.

As regards to the former we naturally kept the DICOM Code Value, Code Meaning and Coding Scheme Designator in dedicated annotation properties.

Regarding the DCM terminology resource, we relied on existing IRIs available from the DICOM DCM ontology[1], available from the National Center of Biomedical Ontology (NCBO) Bioportal, and maintained by the editor of the DICOM Standard. This ontology is available in OWL but organized as a flat list of terms, so we had to re-organize these terms to integrate them properly into our subsumption hierarchy.

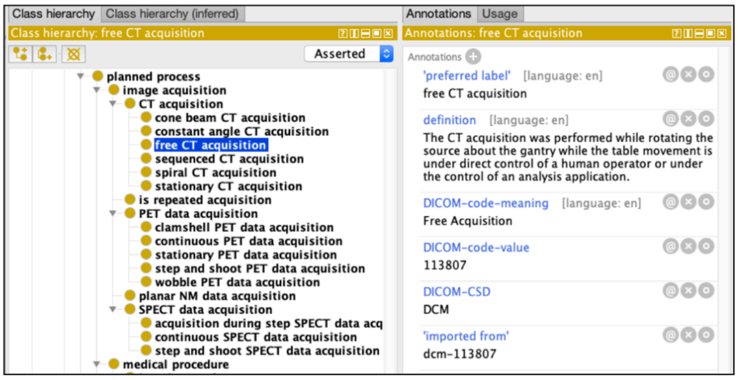
Another aspect of this modeling work was the analysis of DICOM Context Groups referred to in the DICOM Structured Reports templates that we needed to support, especially those related to CT SR dose reports. Context Groups provide flat lists of terms that can be used in a particular context in order to assign a coded value to a particular coded entry. All the items present in each Context Group had to be considered, and potentially dispatched in various places in the overall ontology taxonomy.

An illustrative example is presented Fig.3. In this example, Context Group CID 10013 is referred to in the SR Template TID 10013 CT Irradiation Event Data, in order to precisely specify the detailed characteristics of CT acquisitions. We created corresponding classes in the OntoMEDIRAD ontology, subsumed by a CT acquisition Class, that corresponds to the title of this Context Group. Note that, for DCM terms we kept original IRIs from the DCM ontology, e.g. http://dicom.nema.org/resources/ontology/DCM/113807. Note that we adopted a different (more explicit) label in our skos:prefLabel Annotation property, e.g. 'free CT acquisition' in this particular case.

[1] https://bioportal.bioontology.org/ontologies/DCM

Coding Scheme Designator	Code Value	Code Meaning
DCM	113804	Sequenced Acquisition
SCT	116152004	Spiral Acquisition
DCM	113805	Constant Angle Acquisition
DCM	113806	Stationary Acquisition
DCM	113807	Free Acquisition
SCT	702569007	Cone Beam Acquisition

A - Table CID 10013. CT Acquisition Type (DICOM Part 16)



B – Corresponding part in the OntoMEDIRAD ontology

Figure 3. DICOM Context Groups: illustrative example;

Left part (A): Example of DICOM Context Group ;

Right part (B) Corresponding entities in the OntoMEDIRAD taxonomy

3.5 Sparklis module

Sparklis is a tool allowing MEDIRAD end-users to navigate in the Semantic database of the IRDBB system and to build SPARQL queries.

For achieving this goal the Sparklis tool transparently explores the graph by accessing to it through a SPARQL endpoint, and provides the user information about available data and relations characterizing a particular class. From this information the user can select what information should be specified in the query so that it can be retrieved. The overall (SPARQL) query is built progressively, and translated to the user in natural language.

Therefore, the OntoMEDIRAD ontology uses an additional module (SPARKLISlabels.owl) that allows assigning dedicated labels that are well-suited to the way Sparklis translates SPARQL queries into natural language. These labels are provided in an annotation (called ontomedirad:sparklisLabel) associated to all the object properties and data properties.

A more complete description of the use of Sparklis in MEDIRAD is provided in [4].

4. Next steps

4.1 Validation of the OntoMEDIRAD ontology

The design of the semantic repository of the IRDBB was managed as an iterative process.

It means that the first releases of the ontology were used to implement a first version of the software in charge of creating semantic (RDF) data to populate the semantic repository. This was done first by translating DICOM Dose SR documents as well as basic related image metadata into semantic (RDF) data. Thus, the various software components that produce and use the semantic repository were developed and upgraded progressively, thus ensuring agile and timely adaptation of all the components of the IRDBB system.

The ontology itself still needs to be validated by expert physicists, especially the definitions of the entities.

4.2 Reuse of the OntoMEDIRAD ontology

The OntoMEDIRAD ontology is intended to be reused and extended.

Therefore, the ontology modules can be freely retrieved from the following GitHub repository.

`https://github.com/OsiriX-Foundation/MediradOnto`

The list of files of the current version 1.3.15 is shown Fig. 4.

bfo.owl	12 mars 2020 à 14:37
CHEBI_for_OntoMEDIRAD.owl	12 mars 2020 à 14:37
FMA_for_OntoMEDIRAD.owl	12 mars 2020 à 14:37
IAO_for_OntoSPM.owl	12 mars 2020 à 14:37
MEDIRADClinicalResearchStudies.owl	12 mars 2020 à 14:37
MPATH_for_OntoMEDIRAD.owl	12 mars 2020 à 14:37
ontoMedirad.owl	2 août 2020 à 16:43
PATO_for_OntoMEDIRAD.owl	12 mars 2020 à 14:37
Radionuclides_for_OntoMEDIRAD.owl	12 mars 2020 à 15:41
radiopharmaceuticals.owl	12 mars 2020 à 15:41
skos.rdf	12 mars 2020 à 14:37
SPARKLISlabels.owl	2 août 2020 à 16:36
UO_for_OntoMEDIRAD.owl	12 mars 2020 à 14:37

Figure 4. Files of OntoMEDIRAD Version 1.3.15

References

[1] Xiang Z, Courtot M, Brinkman RR, Ruttenberg A, He Y. OntoFox: web-based support for ontology reuse. BMC Research Notes. 2010; 3:175.

[2] OntoFox tool: http://ontofox.hegroup.org/

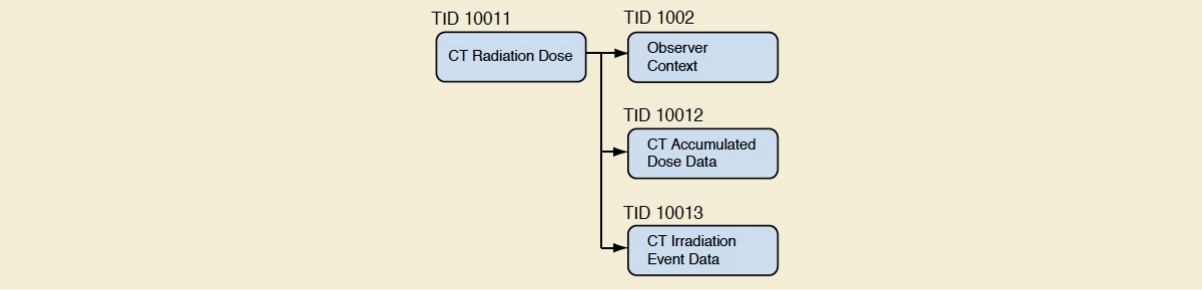
[3] Courtot M, Gibson F, Lister AL, Malone J, Schober D, Brinkman RR, Ruttenberg A. MIREOT: the minimum information to reference an external ontology term. In: International conference on biomedical ontology, ICBO 2009; Buffalo, NY, USA.

[4] Gibaud B. Documentation of the Sparklis tool V1.1. September 2020.

ANNEX 1

This annex provides the hierarchical structure of the templates of the three IODs considered in this version of the ontology, as well as a basic text describing each of them (copied from the DICOM standard Part 16)

CT Radiation Dose SR IOD Templates



TID 10011 CT Radiation Dose

This Template defines a container (the root) with subsidiary Content Items, each of which corresponds to a single CT X-Ray irradiation event entry. There is a defined recording observer (the system or person responsible for recording the log, generally the system).

Accumulated values shall be kept for a whole Study or at least a part of a Study, if the Study is divided in the workflow of the examination, or a performed procedure step. Multiple CT Radiation Dose objects may be created for one Study.

TID 10012 CT Accumulated Dose Data

This general Template provides detailed information on CT X-Ray dose value accumulations over several irradiation events from the same equipment and over the scope of accumulation specified for the report (typically a Study or a Performed Procedure Step).

TID 10013 CT Irradiation Event Data

This Template conveys the dose and equipment parameters of a single irradiation event.

A CT irradiation event is the loading of X-Ray equipment caused by a single continuous actuation of the equipment's irradiation switch, from the start of the loading time of the first pulse until the loading time trailing edge of the final pulse. Any on-off switching of the radiation source during the event shall not be treated as separate events; rather the event includes the time between start and stop of radiation as triggered by the user, e.g., a single sequence of scanning comprised of multiple slices acquired with successive tube rotations and table increments shall be treated as a single irradiation event. Depending on the examination workflow and the anatomical target region the CT irradiation event data may split into multiple instances of this Template for better dose estimation. The irradiation event is the "smallest" information entity to be recorded in the realm of Radiation Dose reporting. Individual Irradiation Events are described by a set of accompanying physical parameters that are sufficient to understand the "quality" of irradiation that is being applied. This set of parameters may be different for the various types of equipment that are able to create irradiation events.

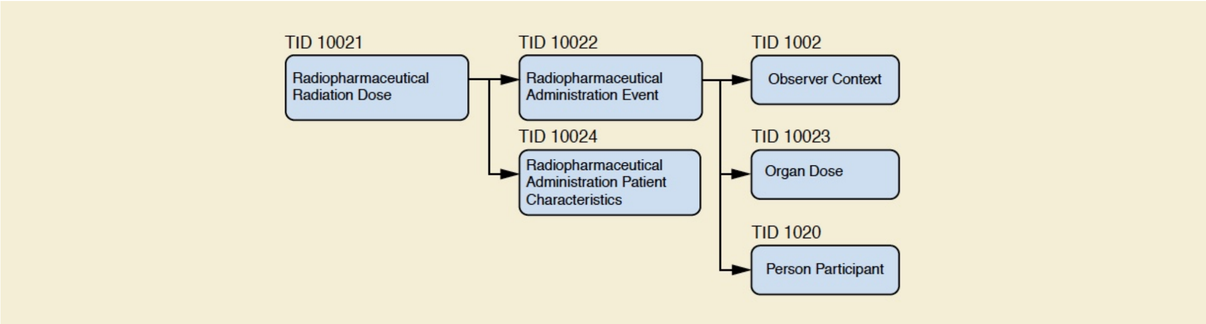
TID 10014 Scanning Length

This Template records details about the scanned region.

TID 10015 CT Dose Check Details

This Template records details related to the use of the NEMA Dose Check Standard (NEMA XR-25-2010).

Radiopharmaceutical Radiation Dose SR IOD Templates



TID 10021 Radiopharmaceutical Radiation Dose

This Template defines a container (the root) with subsidiary Content Items, each of which corresponds to a single Radiopharmaceutical Administration Dose event entry. There is a defined recording observer (the system and/or person responsible for recording the assay of the radiopharmaceutical, and the person administered the radiopharmaceutical). Multiple Radiopharmaceutical Radiation Dose objects may be created for one study.

TID 10022 Radiopharmaceutical Administration Event Data

The Radiopharmaceutical Administration Event conveys the dose and assay and time information of a single radiopharmaceutical event. A Radiopharmaceutical Administration event is one radioactive pharmaceutical administered to a patient.

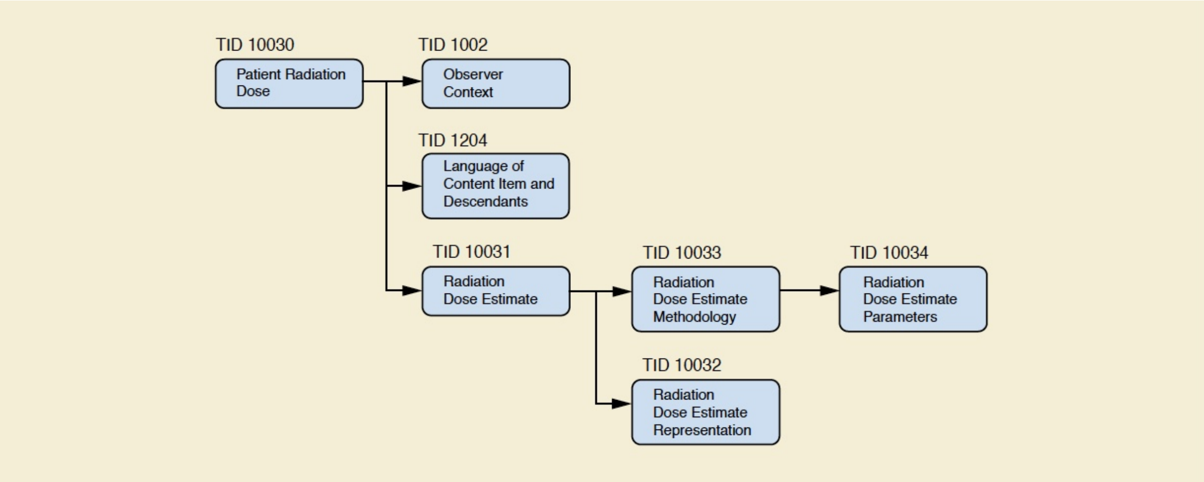
TID 10023 Organ Dose

This Template conveys the information about the dose to a single organ.

TID 10024 Radiopharmaceutical Administration Patient Characteristics

This Template describes the characteristics of the patient that are specific to the current clinical presentation (visit). The characteristics noted may affect the activity received, and how dose is calculated for the patient. Patient Characteristic concepts in this Template, which may replicate attributes in the Patient Study Module, are included here as possible targets of by-reference relationships from other Content Items in the SR tree.

Patient Radiation Dose SR IOD Templates



TID 10030 Patient Radiation Dose

This template defines a container (the root) with subsidiary content items for determining an estimated radiation dose to a patient.

TID 10031 Radiation Dose Estimate

The dose estimate is used to record the results from one analysis method from one or more radiation sources. Organ dose estimates are calculated from one or more irradiation events to a patient. The output from one or more sources of radiation can be used separately or combined to estimate the dose to a patient or individual organs.

TID 10032 Radiation Dose Estimate Representation

Different representations (e.g., images) of the distribution of absorbed energy allow a better understanding of how this energy may affect tissue.

TID 10033 Radiation Dose Estimate Methodology

This template includes the information specific to the organ dose calculation methodology used when estimating dose to individual organs, entire body or a phantom from imaging studies that use ionizing radiation.

TID 10034 Radiation Dose Estimate Parameters

This template includes the parameters that are specific to the Radiation Dose Estimate Method used in the algorithms when estimating dose to individual organs, phantoms, or the entire body from imaging studies that use ionizing radiation.

ANNEX 2

This annex provides the detailed history of changes in the recent versions of the OntoMEDIRAD ontology (versions 1.3.5 to 1.3.15)

Changes of 1.3.5 toward 1.3.6

- Modifications (reported in the GitHub description of version)
- Add Class radiodensity_unit
- Add Class Hounsfield_unit
- Add Class accumulated_decay_event_counts
- Add class counts
- Add class absorded_dose_rate_unit
- Add class gray_per_second
- Add class milligray_per_second
- Add class camera_calibration_factor_unit
- Add class counts_per_second_per_megabecquerel
- Add class energy_deposition_rate_unit
- Add class joule_per_second
- Add class megaelectronvolt_per_second
- Add class curve_fitting_method
- Add class incorporation_function
- Add class constant_incorporation_function
- Add class linear_incorporation_function
- Add class exponential_incorporation_function
- Add class integration_algorithm
- Add class trapezoid_integration_algorithm
- Add class mono_exponential_integration_algorithm
- Add class bi_exponential_integration_algorithm
- Add class tri_exponential_integration_algorithm
- Add class x_exponential_integration_algorithm
- Add class other_integration_algorithm
- Add class fitting_function
- Add class resampled_CT_image_dataset
- Add class resampled_NM_recon_tomo_dataset
- Add class resampled_PET_recon_tomo_dataset
- **Extend UO-extract**
  - Add Class http://purl.obolibrary.org/obo/UO_0000133 #curie
  - Add Class http://purl.obolibrary.org/obo/UO_0000145 #millicurie
  - Add Class http://purl.obolibrary.org/obo/UO_0000146 #microcurie
  - Add Class http://purl.obolibrary.org/obo/UO_0000098 #milliliter
  - Add Class http://purl.obolibrary.org/obo/UO_0000097 #cubic centimeter
- **Extend PATO-extract**
  - Add class http://purl.obolibrary.org/obo/PATO_0001710 #3-D extent
- **Create MPATH-extract**
  - Add Class http://purl.obolibrary.org/obo/MPATH_218 #neoplasm
  - Add Class http://purl.obolibrary.org/obo/MPATH_603 #pathological anatomical entity
- Rename prefLabel of dcm:128487 -> 3D absorbed dose map
- **Add ontology metadata**
  - dcterms:contributor
  - dcterms:title
  - dcterms:description

- Other modifications (NOT reported in the GitHub description of version)
- addition Version name of ontology
- addition class structured_report_of_imaging_study
- addition class creating_structured_report
- addition class DICOM_enhanced_SR_storage_SOP_class
- addition class template_of_structured_report
- addition data property has_end_date
- addition data property has_end_time
- remove class taxonomy_of_non_DICOM_files
- addition class local_energy_deposition
- addition class convolution_based_algorithm
- addition class FFT convolution
- addition class homogeneous matrix convolution
- addition class heterogeneous matrix convolution
- addition class Monte_Carlo_dosimetry_method
- rename radiation_dose_estimate_method absorbed_dose_estimate_method
- rename mean_absorbed_radiation_dose_rate absorbed_dose_rate
- rename mean_absorbed_radiation_dose_rate_per_ROI_at_timepoint absorbed_dose_rate_per_ROI_at_timepoint
- rename mean_absorbed_radiation_dose_rate_per_VOI_at_timepoint absorbed_dose_rate_per_VOI_at_timepoint
- rename mean_total_absorbed_radiation_dose_per_ROI total_absorbed_dose_per_ROI
- rename mean_total_absorbed_radiation_dose_per_VOI total_absorbed_dose_per_VOI
- addition class NM_whole_body_dataset

Changes of 1.3.6 toward 1.3.7

- Correction Bug: Modif label linear_incorporation_mode
- Add Class additional_timepoint
- Modification of all Classes subsumed by post_RAIT_dosimetry_scanning_timepoint
- (to suppress the distance to reference event)
- Add Class time_integrated_activity_unit
- Add Class megabecquerel_second
- Add Class megabecquerel_hour
- Add Class segmentation_dataset
- Add Class HDF_format
- Add Class HDF4_format
- Add Class HDF5_format
- Add Data property has_method_name
- Remove Data property has_brand_name
- Add Class density_image
- **Modify UO_for_OntoMEDIRAD.owl**
  - Add Class http://purl.obolibrary.org/obo/UO_0000182 #density unit
  - Add Class http://purl.obolibrary.org/obo/UO_0000052 #mass density unit
  - Add Class http://purl.obolibrary.org/obo/UO_0000084 #gram per cubic centimeter
  - Add Class http://purl.obolibrary.org/obo/UO_0000083 #kilogram per cubic meter

Changes of 1.3.7 toward 1.3.8

- Add Class soft-tissue
- Add rdfs:label to set_of_subdivisions_of_cardinal_body_parts
- Add Class L3_L5_bone_marrow
- Add Class geometrical_transformation

- Add Object property has_destination_coordinate_space_specified_by
- Add Object property has_source_coordinate_space_specified_by
- Add Class linear_transformation_matrix
- Add Class B_spline_transformation
- Add Class advanced_elastix_transformation

Changes of 1.3.8 toward 1.3.9

- Modif axioms absorbed_dose_rate_per_VOI_at_timepoint
- Modif axioms total_absorbed_dose_per_VOI
- Rename Class L3_L5_bone_marrow to L2_L4_bone_marrow
- Correction of bug on IRIs of megabecquerel.hour megabecquerel.second
- Rename Class timepoint_of_metabolic_radiotherapy -> timepoint_of_internal_radiotherapy
- Rename Class metabolic_radiotherapy -> internal_radiotherapy

Changes of 1.3.9 toward 1.3.10

- Change label has_DICOM_frame_of_reference_UID rdfs:label -> skos:prefLabel
- Add a new import in the ROOT ontology (ontomedirad) called http://medicis.univ-rennes1.fr/ontologies/ontospm/SPARKLISlabels.owl
- (adds an annotation property called sparklis:sparklisLabel to most Object properties and data properties)
- Remove Object Property is_device_setting (duplicate of is_device_setting_of) from ontomedirad and sparklislabels
- Modify definition of is_device_setting_of (to extend semantics to methods)
- Modify Class 'device setting' : remove axiom concerning is_device setting_of
- Remove Object Property has_measure
- Remove Object Property has_caracteristic
- Modify Class Image acquisition protocol: add a definition
- Modify Class CT acquisition protocol: add a definition
- Modify Class NM acquisition protocol: add a definition
- Modify Class PET acquisition protocol: add a definition
- Modify Class effective_dose_evaluation_method: add a definition
- Modify Class size_specific_dose_estimation_method_for_CT: add a definition
- Modify Class analytical_reconstruction_algorithm: add a definition
- Modify Class statistical_iterative_reconstruction_technique: add a definition
- Modify Class bayesian_reconstruction_technique: add a definition
- Remove Class radiation_dose_estimate_parameters
- Modify Class reconstruction_method_with_attenuation_correction: add a definition
- Modify Class reconstruction_method_without_attenuation_correction: add a definition
- Modify Class reconstruction_method_with_PSF_based_correction: add a definition
- Modify Class reconstruction_method_without_PSF_based_correction: add a definition
- Modify Class reconstruction_method_with_scatter_correction: add a definition
- Modify Class reconstruction_method_without_scatter_correction: add a definition
- Modify Class reconstruction_method_with_filtering: add a definition
- Modify Class water_equivalent_diameter_method: : add a definition
- **Re-generate the PATO extract with two additional classes**
    - http://purl.obolibrary.org/obo/PATO_0001019 #mass density
    - http://purl.obolibrary.org/obo/PATO_0001353 #volumetric density

Changes of 1.3.10 toward 1.3.11

- Add Class case_report_form
- Add Class CRF_WP3
- Add Class CRF_WP3_IUCT_version
- Add Class CRF_WP3_RMH_version

- Add Class CRF_WP3_UMR_version
- Add Class CRF_WP3_UKW_version

Changes of 1.3.11 toward 1.3.12

- Add Data property has_rank
- Modif definition internal_radiotherapy
- Add Class 3D_dosimetry_of_TRT_using_time_integration_on_activity
- Add Class 3D_dosimetry_of_TRT_using_time_integration_on_aborbed_dose_rates
- Add Class 2D_dosimetry_of_TRT
- Add Class hybrid_dosimetry_of_TRT
- Add Class 3D_dosimetry_of_CT

Changes of 1.3.12 toward 1.3.13

- Modification Annotation skos:prefLabel Class resampled_NM_recon_tomo_dataset
- Modification Annotation skos:prefLabel Class resampled_PET_recon_tomo_dataset
- Remove Object Property has_caracteristic
- Add Class dosimetry_of_TRT

Changes of 1.3.13 toward 1.3.14

- Add Class author
- Change superclass of hybrid_dosimetry_of_TRT
- Change superclass of 3D_dosimetry_of_CT
- Change Sparklis annotation of object property is_about_procedure

Changes of 1.3.14 toward 1.3.15

- Modif definition Class dosimetry_of_TRT
- Add Class volume_measurement_datum
- Add Class CT_segmentation_in_SPECT_calibration
- Add Class SPECT_CT_calibration
- Change superclass of CT_number_calibration_curve -> model
- Add class element_of_CT_number_calibration_curve
- Add class radiodensity_measurement_datum
- Add class nominal_radiodensity_measurement_datum
- Add class image_derived_radiodensity_measurement_datum
- Add Class counts_per_ROI
- Add Class counts_per_VOI
- Change superclass of radiopharmaceutical_volume -> volume_measurement_datum
- Change superclass of SPECT_recovery_coefficient_curve -> model
- Add class element_of_recovery_coefficient_curve
- Add Data property has_reference_calibration_date (Sparklis label : calibration date)
- Add Class ratio_measured_activity_to_true_activity
- Add Class image_derived_volume_measurement_datum
- Add Class nominal_volume_measurement_datum
- Change superclass of 'radiopharmaceutical volume' -> nominal_volume_measurement_datum
- Add Class CT_calibration