

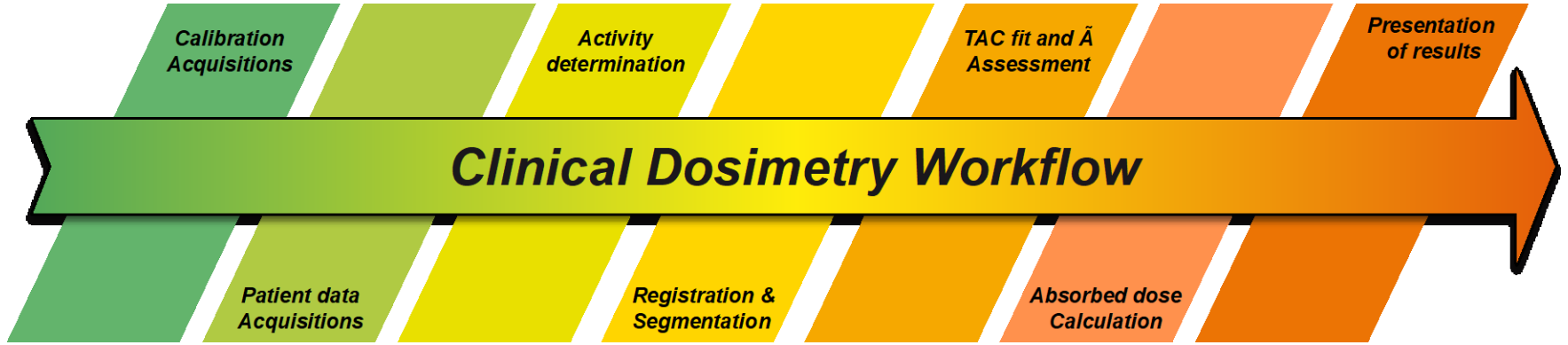
OpenDose3D: a free/open clinical dosimetry software for nuclear medicine

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Declaration of interest

- Manuel Bardiès supervises a PhD project sponsored by DOSIsoft
- José Fragoso (PhD student) is sponsored by DOSIsoft
- Development of OpenDose3D was made within the MEDIRAD project

Clinical dosimetry workflow (CDW)



Bardiès and Gear (2021) Scientific Developments in Imaging and Dosimetry for Molecular Radiotherapy.
Clinical Oncology 33(2) 117-124

- Absorbed dose calculation is ONE part of the clinical dosimetry workflow
- All steps should be treated/addressed with the same care!
- Global uncertainty resulting from the whole CDW?

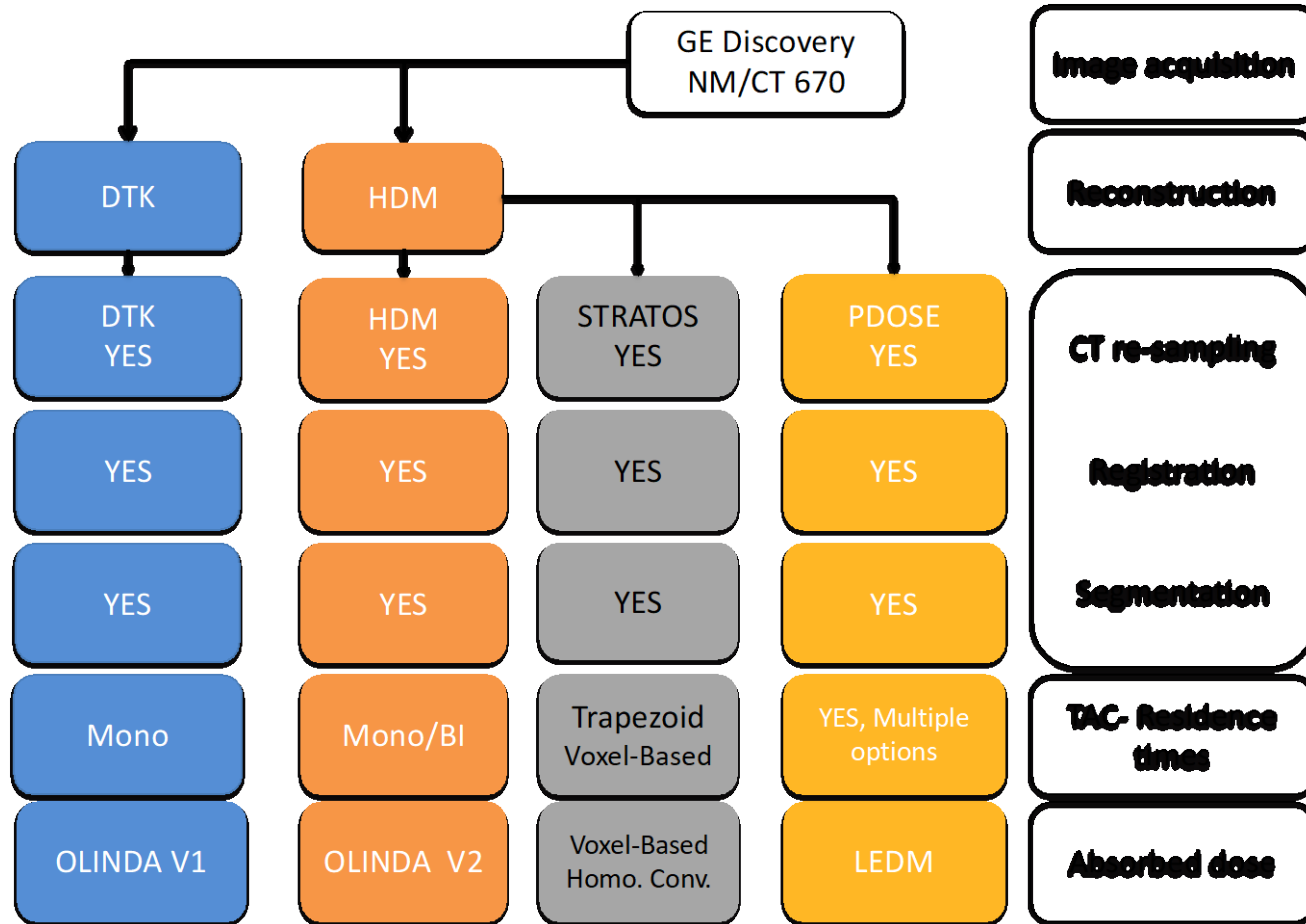
Clinical dosimetry software

	Academic	Commercial
Available	?	✓
Free	✓	-
Maintained	-	✓
Documented	+/-	+/-
CE-marked/FDA approved	-	✓

- How to benchmark?

Comparing software?





MEDICAL PHYSICS

The International Journal of Medical Physics Research and Practice

Research Article | [Open Access](#) | [CC](#) [i](#)

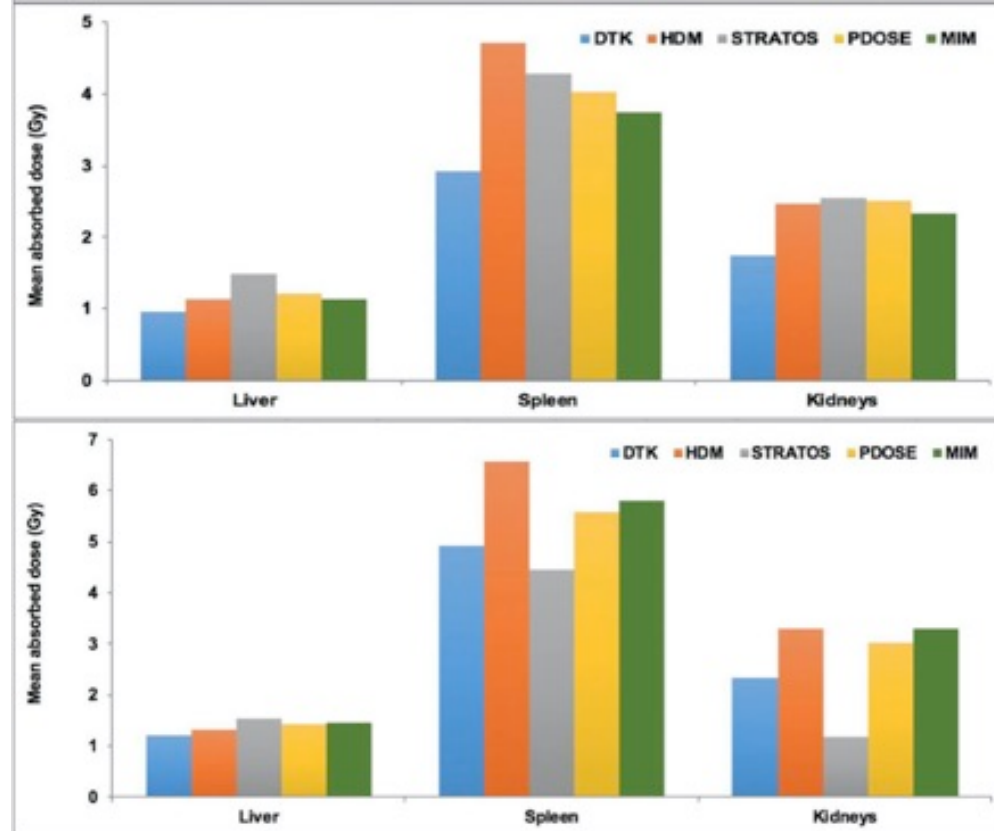
Comparison of commercial dosimetric software platforms in patients treated with ^{177}Lu -DOTATATE for peptide receptor radionuclide therapy

Erick Mora-Ramirez [✉](#), Lore Santoro, Emmanuelle Cassol, Juan C. Ocampo-Ramos, Naomi Clayton, Gunjan Kayal, Soufiane Chouaf, Dorian Trauchessec, Jean-Pierre Pouget, Pierre-Olivier Kotzki, Emmanuel Deshayes, Manuel Bardiès ... [See fewer authors](#) [^](#)

First published: 06 July 2020 | <https://doi.org/10.1002/mp.14375> | Citations: 1

Still

- Comparison was done BUT
- Some choices were made to make the comparison possible
- Every manufacturer could object!
- No common reference, metrics...



Comparing software?



Fig. 1. Diagram of the proposed workflows in MRT and SRT TPSs. Workflow personalization is available for several TPSs.

Comparing software?

Table 6

Zero to first time
SurePlan-MRT, if
activity at inject
radionuclide. In t
administered acti
Intermediary valu
fraction of A_{Adm})
TAC integration,
decay of the radi

TPS
QDose
PlanetDose
HERMES Organ
HERMES Voxel
SurePlan- MRT

Table 9

Absorbed dose calculation methods implemented by the TPSs. DVK= Dose-voxel kernel; MC= Monte Carlo. *in Q-Suite, DVK is implemented only for post-treatment dosimetry, not for pre-treatment dose simulation.

TPS	Voxel S-value	Local deposition	Convolution DVK in homogenous media	Semi-MC
QDose	✓	×	×	×
PlanetDose, PlanetDose-SRT	✓	✓	✓	×
HERMES Voxel	×	×	×	✓
SurePlan-Liver	×	✓	×	×
SurePlan-MRT	✓	×	×	×
Simplicity	×	✓	×	×
Q-Suite	×	✓	✓*	×
RapidSphere	×	✓	×	×

Our wish list...

- Specific workflows (adapted to pathologies/isotopes/...)
- Import/export features ...should include import/export DICOM RT-Struct and RT-Dose.
- Internal “sanity” checks should be performed automatically
- A modular approach ... in order to allow step-by-step processing (providing checkpoints) or the possibility to perform a dosimetry study in different sessions
- The calibration process should be well described, or even better, a “calibration module” should be available
- Storing of intermediary results (segmentation, registration...) and a history of the processes performed should be available to allow traceability and a retrospective processing of dosimetric studies
- The output format should be standardized ... at least well documented
- Uncertainty analysis should be implemented within the workflow.

Comparing software?

Codes may address only some parts of the CDW.

Need for:

- Defining the *metrics* to benchmark clinical dosimetry
- Defining standards (DICOM and others) to ensure traceability?
- Defining *check-points* in clinical dosimetry
- Designing virtual patient to test the CDW?
- Designing (digital?) test objects for addressing specific dosimetry steps
- Software for benchmarking/commissioning of codes?

https://therapy.snmami.org/SNMMI-THERAPY/Dosimetry_Challenge.aspx

www.dositest.org

www.opendose.org

*<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8075532/>

Why OpenDose3D?

Existing clinical dosimetry software

- Academic
- Commercial

Both have advantages/drawbacks

OpenDose3D:

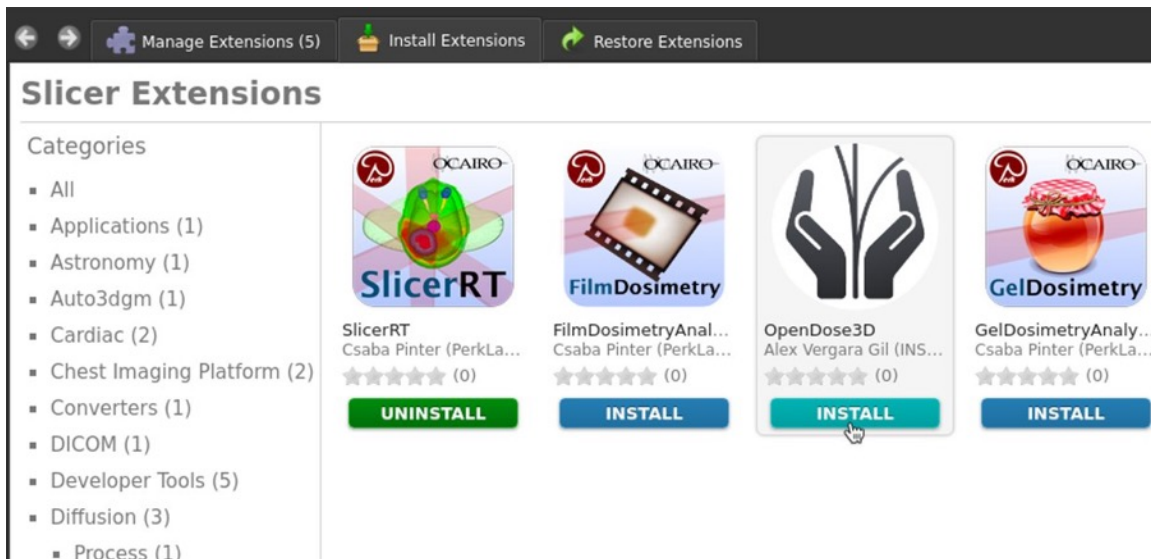
- Open-source software
- Freely available

Based on 3D Slicer:

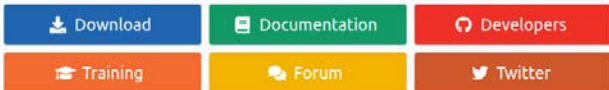
- Use cool features of 3D Slicer
- Develop missing features

OpenDose3D: Available as 3D Slicer plugin

- Designed for image based (patient specific) dosimetry
- Using different absorbed dose calculation algorithms



3D Slicer image computing platform

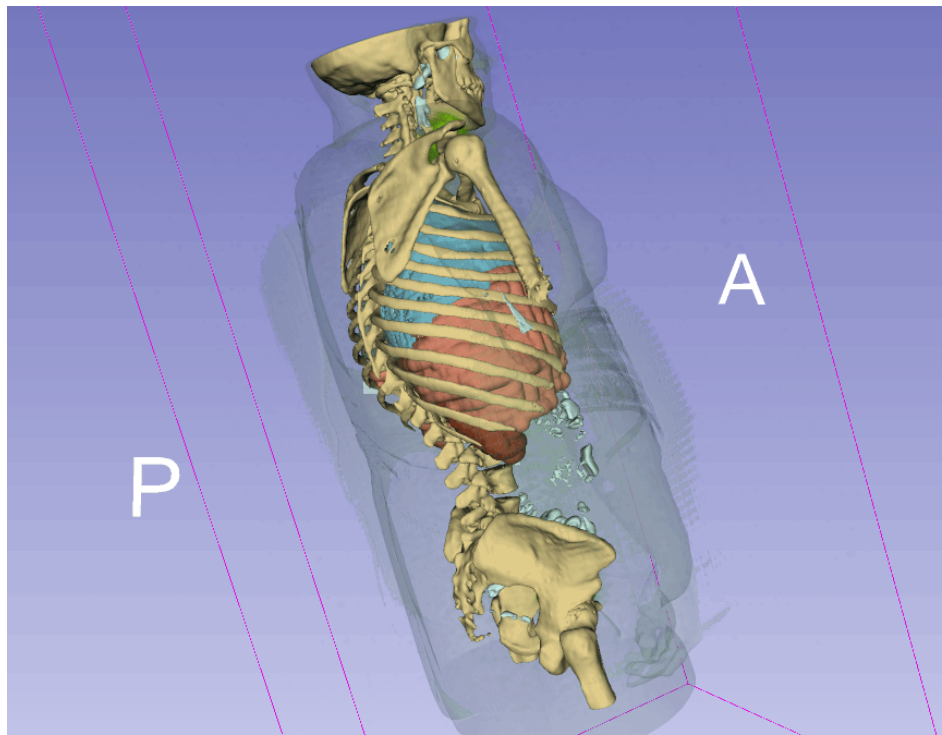


3D Slicer is a **free, open source** and **multi-platform** software package widely used for medical, biomedical, and related imaging research.

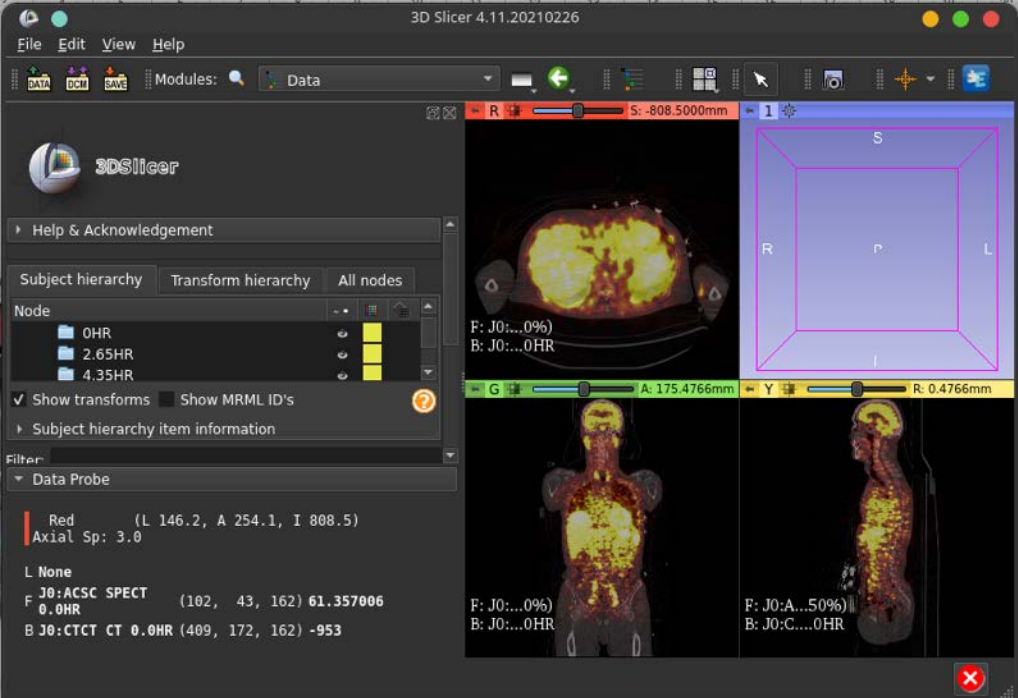
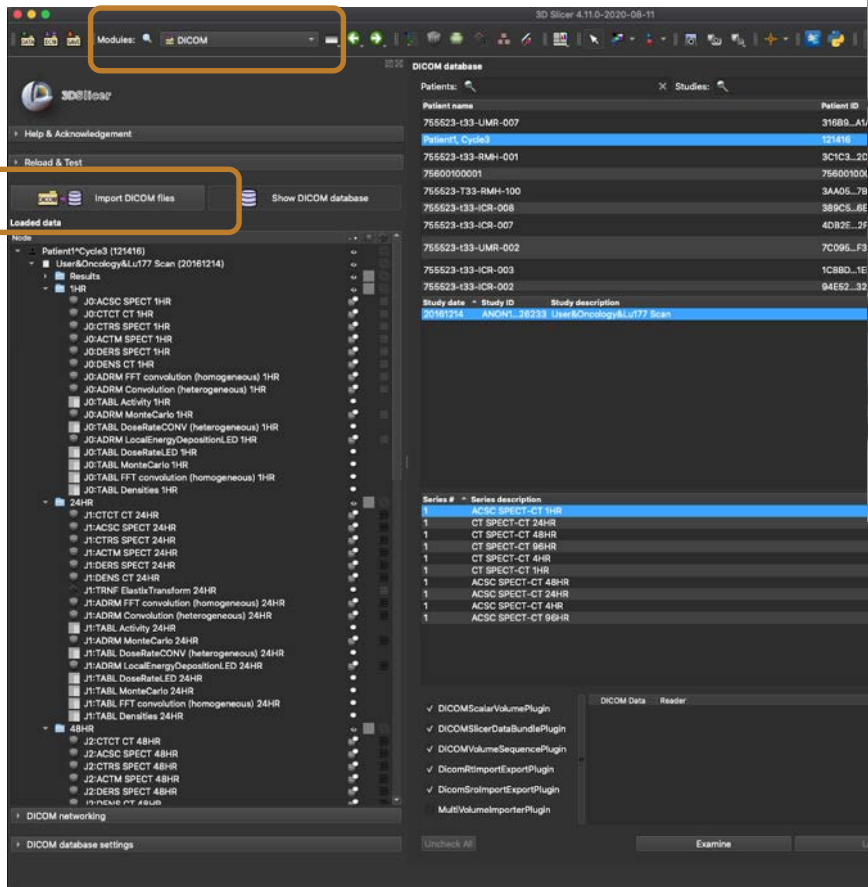
<https://www.slicer.org/>

- Analysis (registration / segmentation)
- Visualization (volume rendering)
- A free, **open source** software
- Available in multiple operating systems: Linux, Mac OSX and Windows.
- Extensible, with powerful **plug-in capabilities** for adding algorithms and applications.

There are no restrictions on use, but 3D Slicer is **not approved for clinical use** and is intended for **research**. Permissions and compliance with applicable rules are the responsibility of the user.



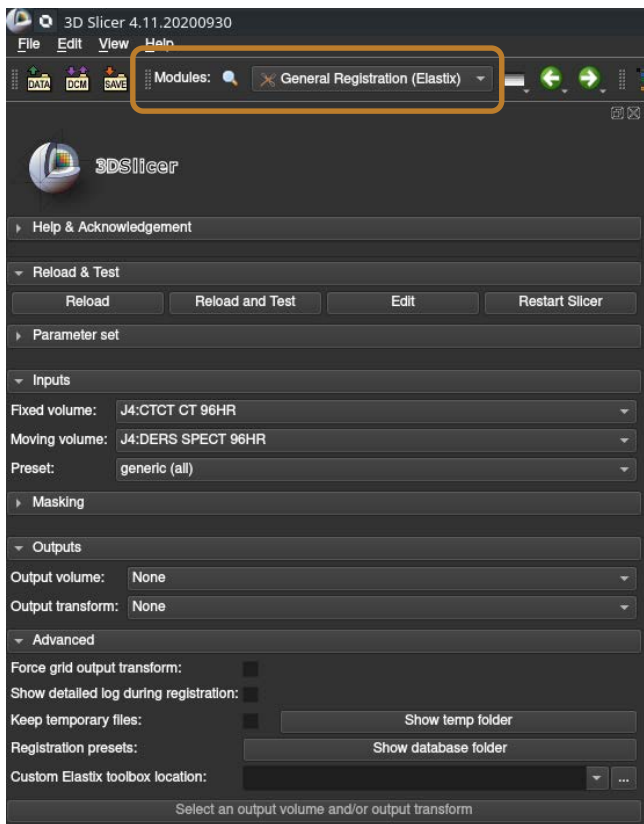
3D Slicer



Features of 3D Slicer:

- DICOM RT (I/O)
- Display
- Segmentation
- Registration

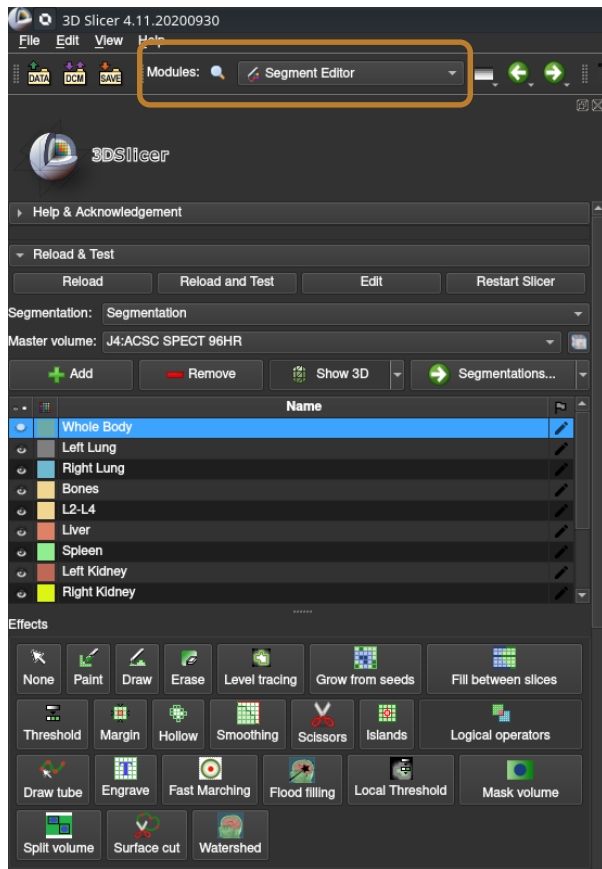
Slicer 3D features: Registration



Use of the Elastix module in Slicer for time point registration

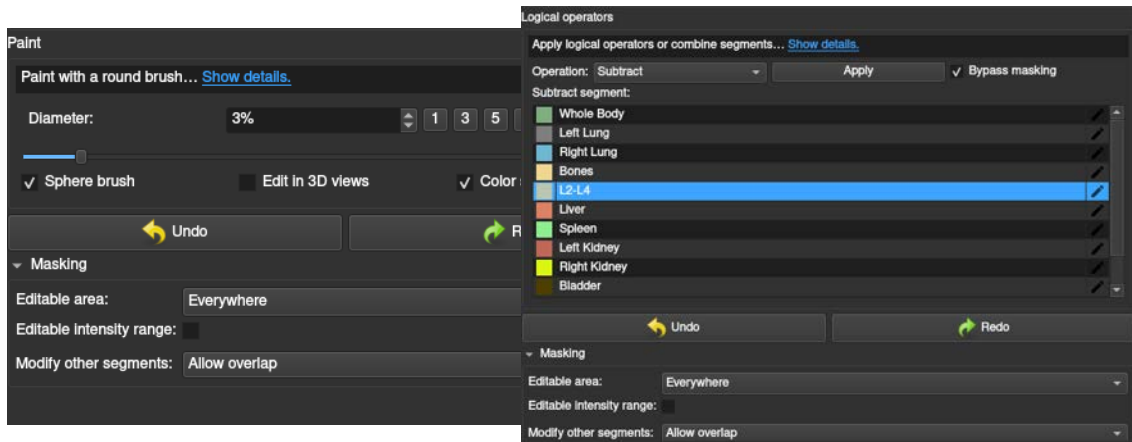
- Rigid and Elastic registrations
- The registrations are stored as Transformation fields, without modifying the original images
- Implicit inverse transformation while querying images for statistics
- Several objects (images, segmentations, even other transform fields) may share the same transformation
- Visualization tools for assessing the registration.
- Possibility to implement extra linear transformations (semi-automatic) before the elastic step to improve results

Slicer 3D features: Segmentation



Use of Slicer full toolset for Segmentation

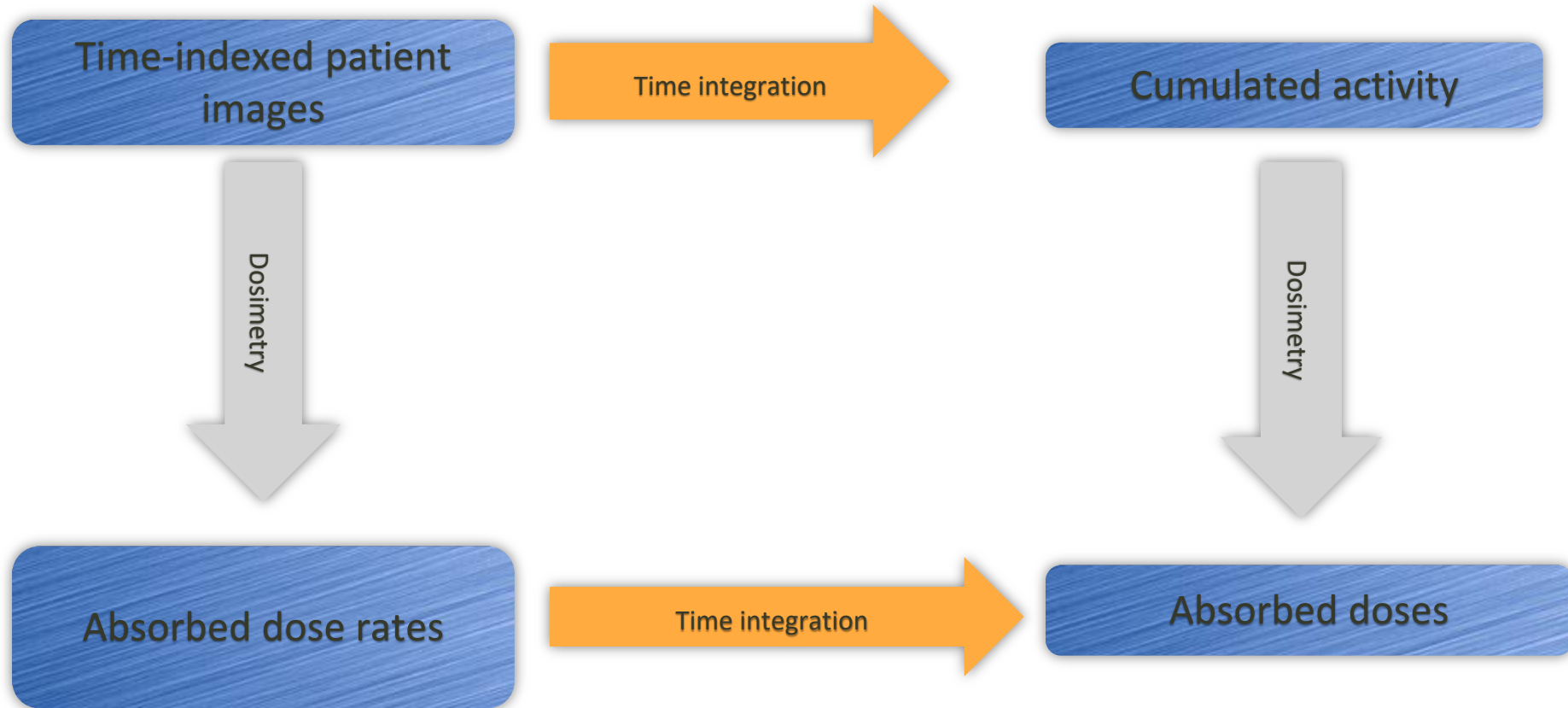
- Various options to define structures
- Each tool contains full customizations
- One segmentation per time point if necessary
- Some AI tools are available for segmentation



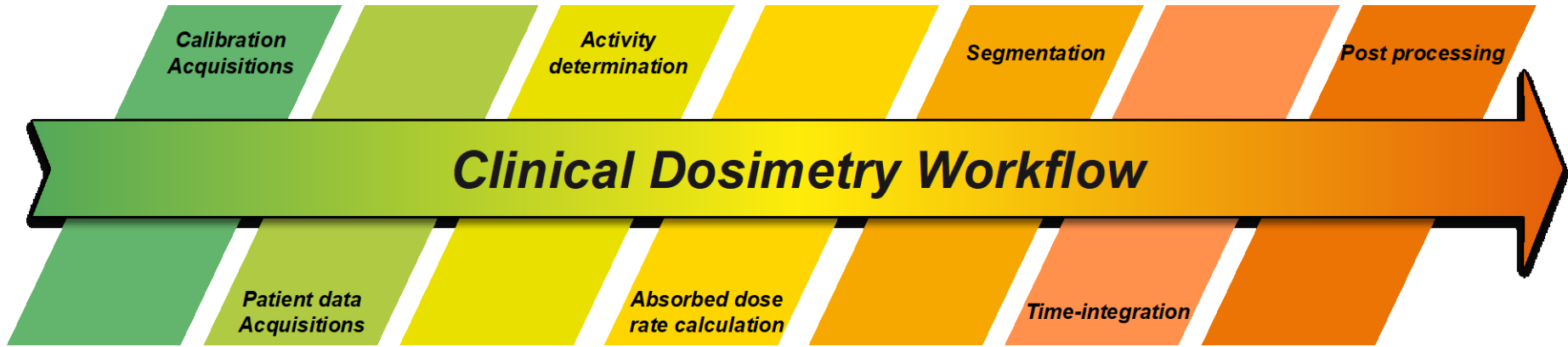
OpenDose3D data workflow

- **Data workflows defined in the Medirad project**
- **Modular design (each step has data input and data output that is preserved on saving)**
- **Possibility to import/export intermediary results at every stage**
- **Integration of the calibration module**
- **Different time-dependent variable integration**
- **Different absorbed dose calculation algorithms**

Data processing workflow?

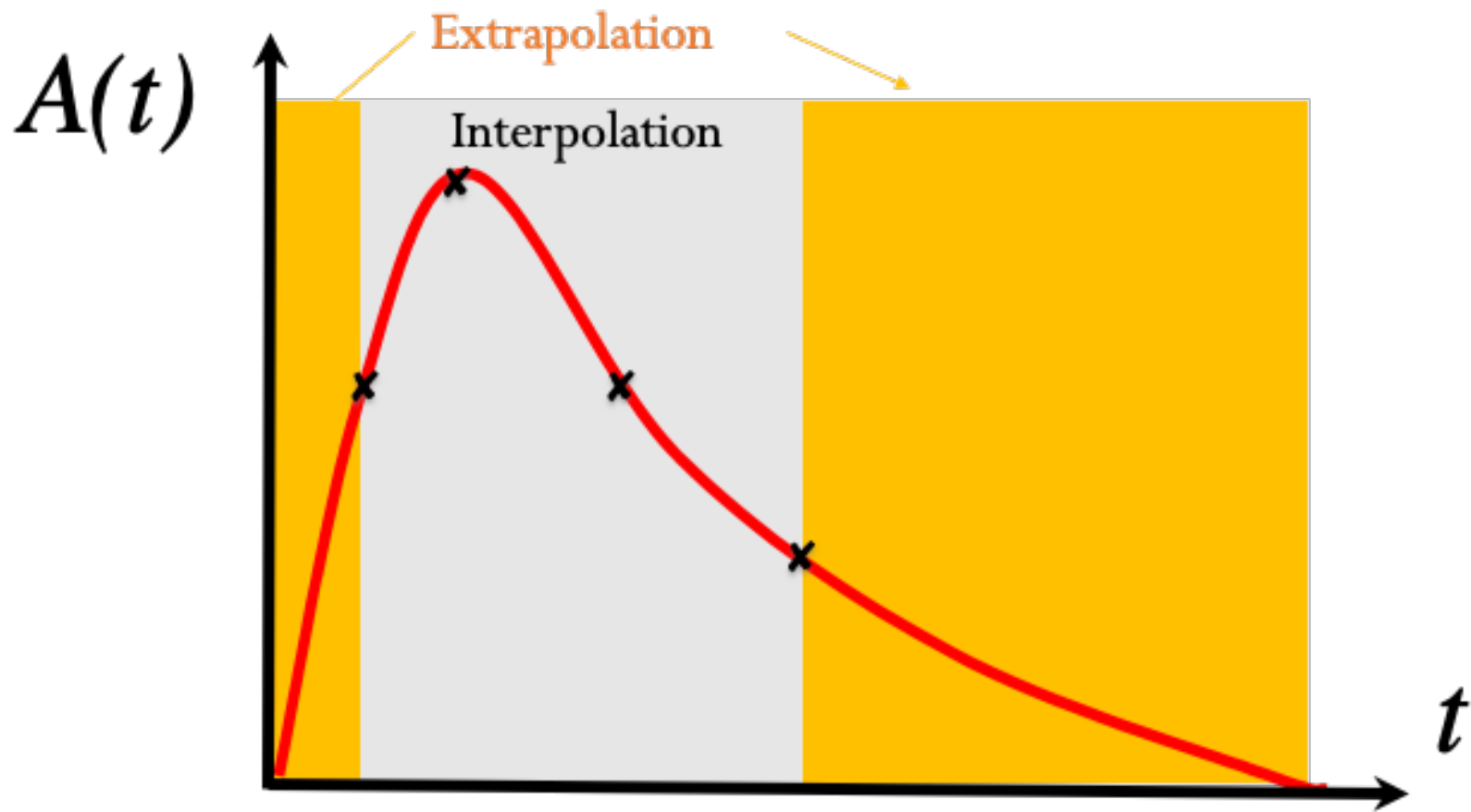


Alternate Clinical Dosimetry Workflow?

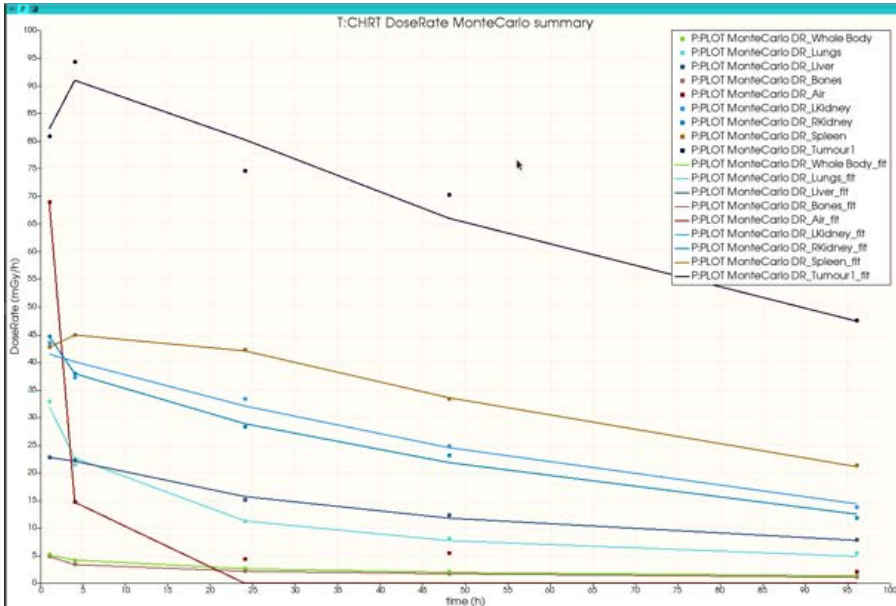
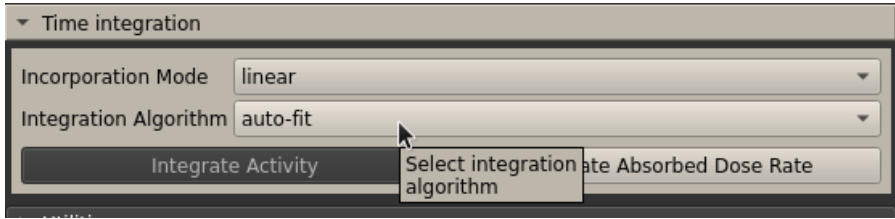


- Already implemented in some codes
- Various implications...
- Previous CDW also possible

TAC fitting

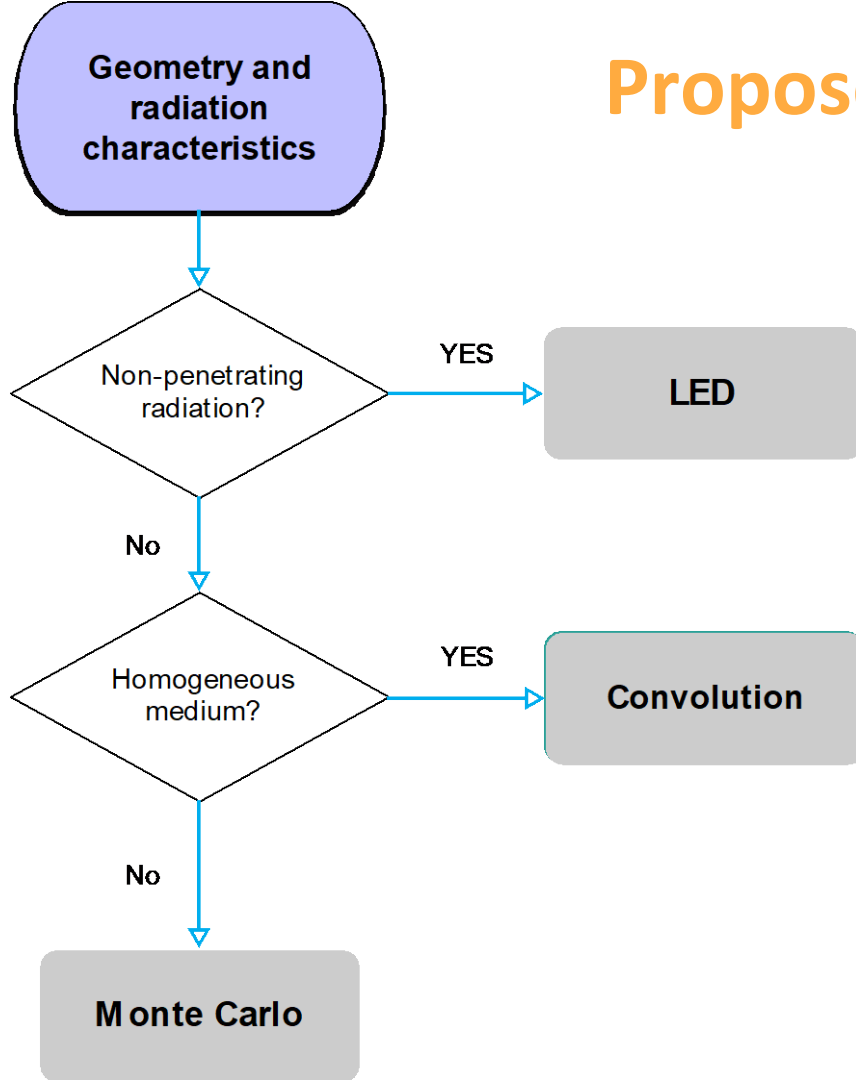


Time integration

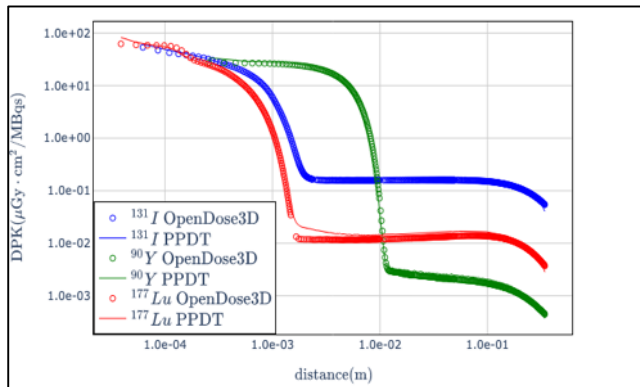
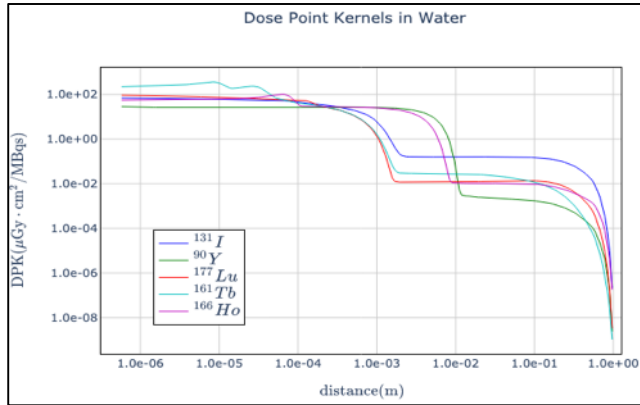


- Time integration:
 - ADR integration
 - Activity integration
- Several fit function implemented
 - Mono-Bi-Tri-X-Exponential
 - Auto selection of best fit using bayesian stats
- Handling of extrapolations:
 - 0 to first time-point
 - Last time-point to infinity

Proposed selection algorithm



Absorbed dose calculation algorithms



Local Energy Deposition (LED) w/o Density correction

- Use of ICRP 107 radionuclide emission database (electrons/beta only)

Convolution (VSV)

- Use of GATE 8.2 (all emissions - ion source) to generate DPK in spherical shells with effective radius correction*
- Home-made python script to generate VDK by Monte Carlo integration in selected voxel sizes and material.
- Interpolation of precalculated VDK to real voxel size of NM images
- Possibility to implement density correction

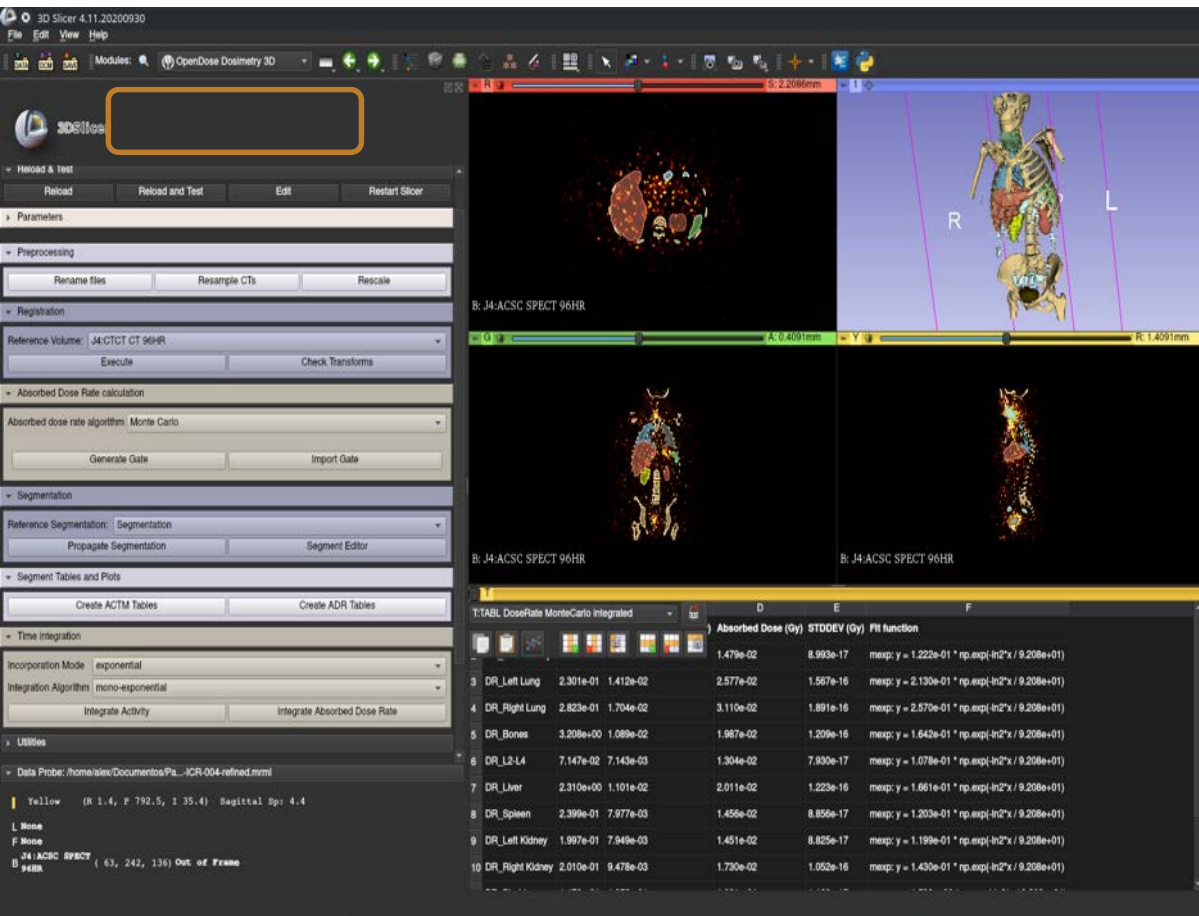
Monte Carlo (MC)

- Generation of GATE macros for simulations (all emissions - ion source)
- Automatic loading of GATE results (with correct path)

Comparison vs data from Papadimitroulas,
Med. Phys. 39(8), 2012

*Janicki, Med. Phys. 31(4), 2004

OpenDose3D



The screenshot shows the OpenDose3D software interface. The main window displays a 3D anatomical model of a human torso, segmented into various organs and tissues. The interface includes a menu bar (File, Edit, View, Help), a toolbar, and a sidebar with various processing options. A table at the bottom displays dosimetry data for various organs.

	D	E	F
	Absorbed Dose (Gy)	STDEV (Gy)	Fit function
1	1.479e-02	8.993e-17	$\text{mexp: } y = 1.222e-01 * \text{np.exp}(-\ln^2 x / 9.208e+01)$
3 DR_Left Lung	2.301e-01 1.412e-02	2.577e-02	$\text{mexp: } y = 2.130e-01 * \text{np.exp}(-\ln^2 x / 9.208e+01)$
4 DR_Right Lung	2.823e-01 1.704e-02	3.110e-02	$\text{mexp: } y = 2.570e-01 * \text{np.exp}(-\ln^2 x / 9.208e+01)$
5 DR_Bones	3.208e+00 1.089e-02	1.987e-02	$\text{mexp: } y = 1.642e-01 * \text{np.exp}(-\ln^2 x / 9.208e+01)$
6 DR_L2-L4	7.147e-02 7.143e-03	1.304e-02	$\text{mexp: } y = 1.078e-01 * \text{np.exp}(-\ln^2 x / 9.208e+01)$
7 DR_Liver	2.310e+00 1.101e-02	2.011e-02	$\text{mexp: } y = 1.661e-01 * \text{np.exp}(-\ln^2 x / 9.208e+01)$
8 DR_Spleen	2.399e-01 7.977e-03	1.456e-02	$\text{mexp: } y = 1.203e-01 * \text{np.exp}(-\ln^2 x / 9.208e+01)$
9 DR_Left Kidney	1.997e-01 7.949e-03	1.451e-02	$\text{mexp: } y = 1.199e-01 * \text{np.exp}(-\ln^2 x / 9.208e+01)$
10 DR_Right Kidney	2.010e-01 9.478e-03	1.730e-02	$\text{mexp: } y = 1.430e-01 * \text{np.exp}(-\ln^2 x / 9.208e+01)$

Specific developments:

- Data workflow
 - Saved I/O
- Time integration
 - ADR
 - TAC
- Dosimetry algorithms:
 - Local Energy Deposition (LED)
 - Convolution (VDK)
 - Monte Carlo (GATE)

Validation for ^{90}Y (SIRT)

Comparison between OD3D algorithms for a sample clinical case

Absorbed doses (Gy)					
Algorithm	Liver	Liver Perfused	Lesion	Healthy Liver	Healthy Liver Perfused
LED	28.90	137.70	153.60	7.22	78.60
Homogeneous Convolution	30.24	143.20	159.70	7.73	82.11
Heterogeneous Convolution	29.31	138.70	153.90	7.64	82.24
Monte Carlo	29.03	136.91	152.31	7.60	79.98

Tested on 5 HCC patients treated by Trans-Arterial Radio-Embolization (Physica Medica 64:245-251, 2019).

Same segmentation applied for all methods. Differences in calculated absorbed doses between algorithms are small, therefore the fastest method (LED) is recommended for this application

Validation for ^{177}Lu (IAEA CRP)

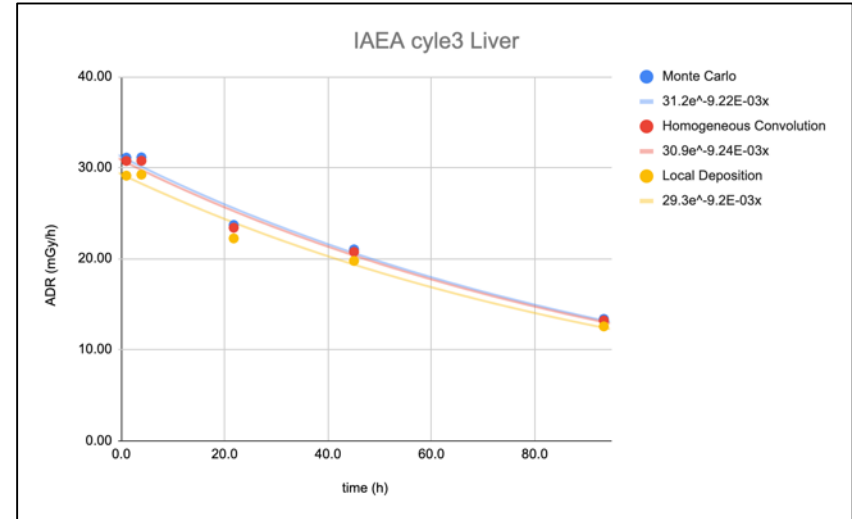
Patient from IAEA CRP Project E2.30.05 on “Dosimetry in Radiopharmaceutical therapy for personalized patient treatment”. Comparison with Dosisoft PlanetDose®

Software	LL	RL	LK	RK	Spleen	Liver	RB
OpenDose 3D	2.64	2.34	36.2	38.1	41.8	29.9	3.51
PDOSE	2.52	2.45	35.2	36.9	40.8	28.8	3.28
Relative diff	-4.5%	4.7%	-2.8%	-3.1%	-2.4%	-3.7%	-6.6%

Absorbed dose rates after 1h using LED WITHOUT density correction
(OpenDose 3D is taken as reference) (mGy/h)

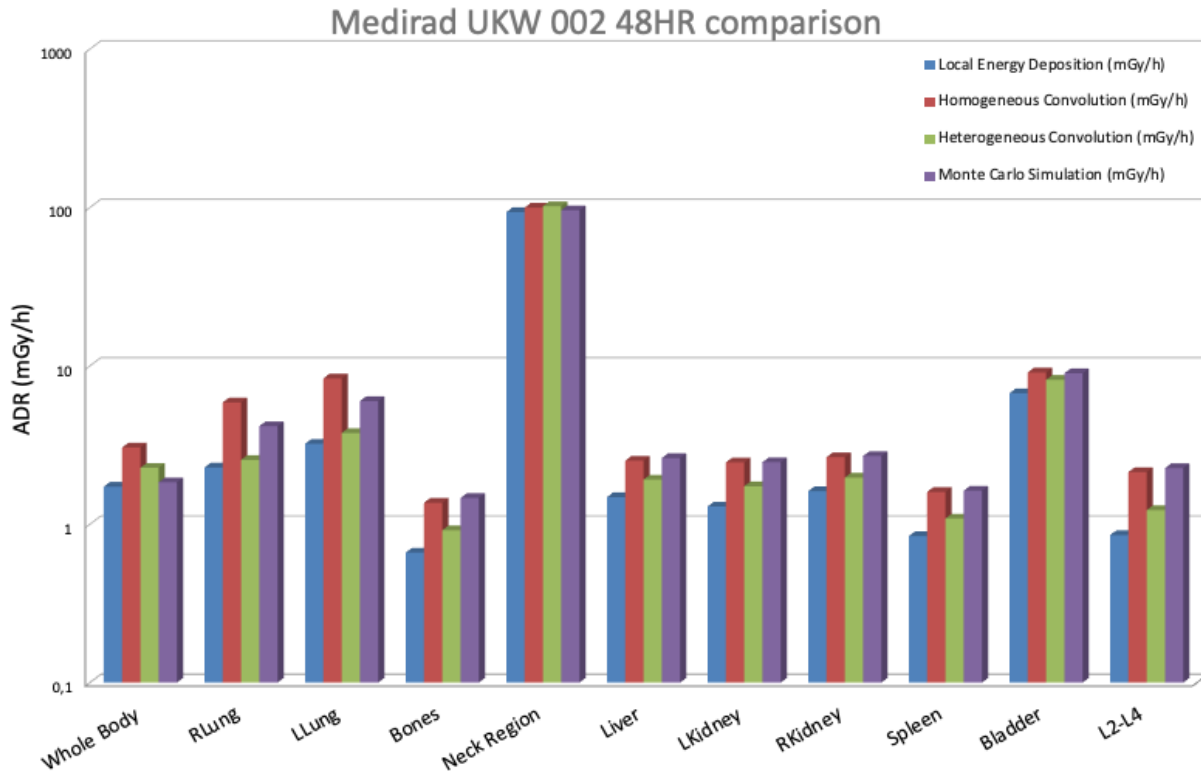
Software	LL	RL	LK	RK	Spleen	Liver	RB
OpenDose 3D	7.77	8.66	35.9	37.6	40.8	29.2	3.64
PDOSE	5.08	5.00	35.5	36.9	40.6	28.2	3.42
Relative diff	-34.6%	-42.3%	-1.1%	-1.9%	-0.5%	-3.4%	-6.0%

Absorbed dose rates after 1h using LED WITH density correction
(OpenDose 3D is taken as reference) (mGy/h).



Equivalent results obtained with MiM Sureplan®

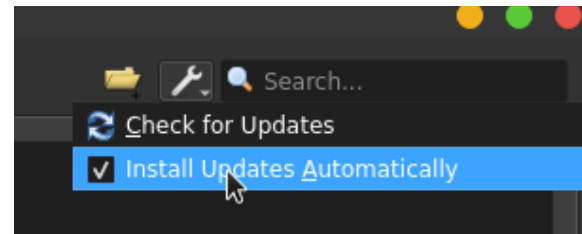
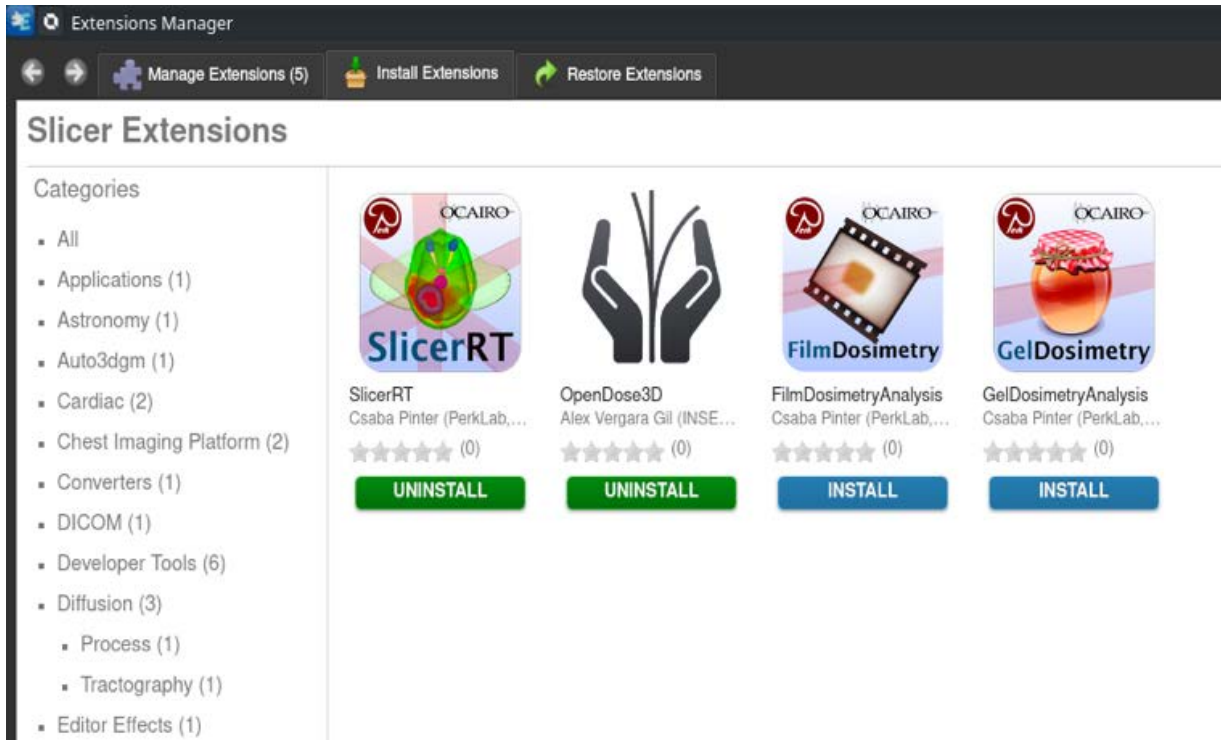
Validation for ^{131}I (MEDIRAD)



Comparison of \pm ADR methods in a Thyroid cancer patient with thyroidectomy and post-therapy with ^{131}I .

Influence of the high gamma contribution.

The OpenDose3D Software



- Integrated into the Slicer official modules under the category of **Radiotherapy**
- Easy update inside the extension manager

The OpenDose3D Software

Fully open source, source available at <https://gitlab.com/opendose/opendose3d>

The screenshot shows the GitLab interface for the project 'SlicerOpenDose3D'. The browser address bar shows 'gitlab.com/opendose/opendose3d'. The page header includes the GitLab logo and navigation menus for 'Projects', 'Groups', and 'More'. A search bar is located in the top right. A yellow notification banner at the top states: 'Please ensure your account's [recovery settings](#) are up to date.'

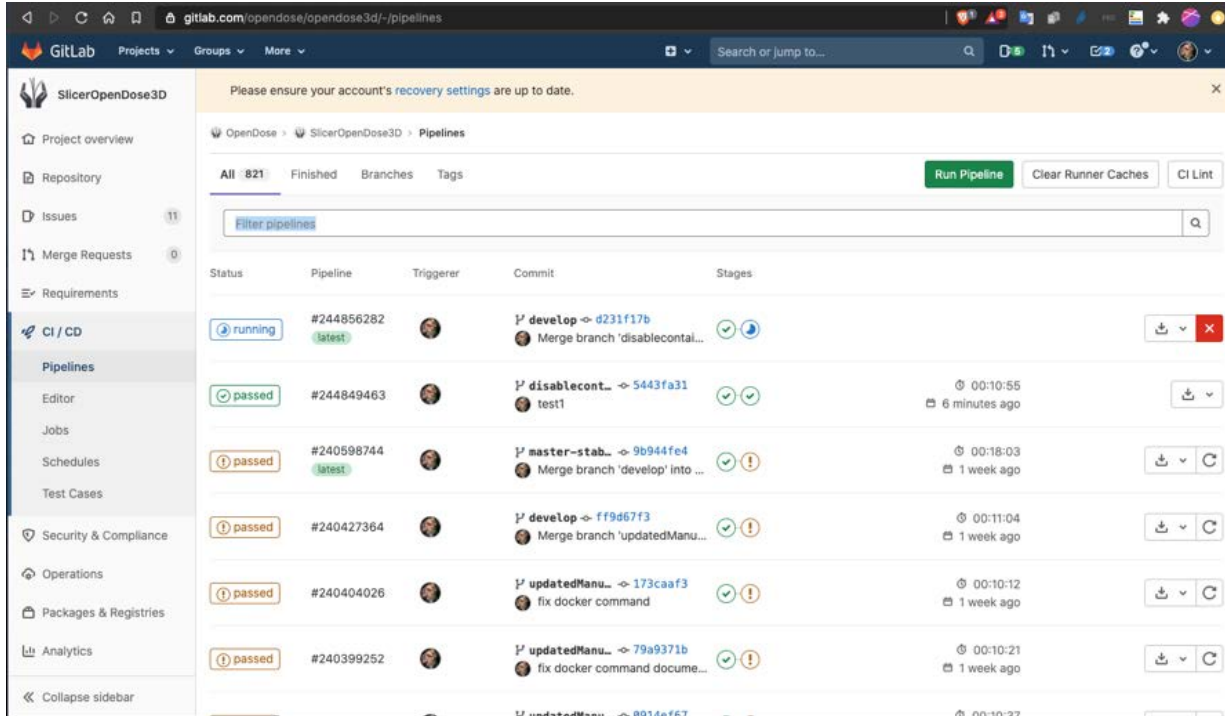
The main content area displays the project details for 'SlicerOpenDose3D', which is a public project (indicated by a globe icon) with a 'GDPR' badge. The project ID is 15399086, and there is a 'Leave project' link. The project description is '3d Slicer Extensi...'. Key statistics include 517 Commits, 2 Branches, 0 Tags, 717 KB Files, and 643.8 MB Storage. A description states: 'This project implements a Slicer3D module aiming for molecular radiotherapy dosimetry'.

Below the description is a progress bar for CI/CD pipelines with the following status: pipeline (passed), oil best practices (passing), build (passing), and coverage (0%).

The current branch is 'develop' in the 'opendose3d' repository. Action buttons include 'History', 'Find file', 'Web IDE', and 'Clone'. A recent commit is shown: 'Merge branch 'updatedManual' into 'develop'' by Alex Vergara Gil, authored 6 days ago, with commit hash ff9d67E3.

At the bottom, there are buttons for 'README', 'Apache License 2.0', 'CI/CD configuration', 'Add CHANGELOG', and 'Add CONTRIBUTING'. Additional features include 'Auto DevOps enabled' and 'Add Kubernetes cluster'.

The OpenDose3D Software



The screenshot displays the GitLab Pipelines interface for the SlicerOpenDose3D project. The page shows a list of pipeline runs with columns for Status, Pipeline ID, Triggerer, Commit, and Stages. The first pipeline is currently running, while the others have passed.

Status	Pipeline	Triggerer	Commit	Stages
running	#244856282		develop -> d231f17b Merge branch 'disablecont...	
passed	#244849463		disablecont... -> 5443fa31 test1	00:10:55 6 minutes ago
passed	#240598744		master-stab... -> 9b944fe4 Merge branch 'develop' into ...	00:18:03 1 week ago
passed	#240427364		develop -> ff9d67f3 Merge branch 'updatedManu...	00:11:04 1 week ago
passed	#240404026		updatedManu... -> 173caaf3 fix docker command	00:10:12 1 week ago
passed	#240399252		updatedManu... -> 79a9371b fix docker command docum...	00:10:21 1 week ago

Full Test suite created for this software covering 100% of the code, it contains data samples from a real patient [1].

Use of gitlab. Tests are automatically executed in every merge.

The tests check that the desired behaviour doesn't change after every modification.

[1] The sample patient data images used were shared as part of IAEA Coordinated Research Project (CRP) on "Dosimetry in Radiopharmaceutical therapy for personalized patient treatment"(E2.30.05).

Conclusions

- OpenDose3D allows users to perform personalised internal dosimetry
- It is NOT and *WILL NOT be* FDA approved/CE-marked
- Designed to allow traceability of the clinical dosimetry workflow (CDW)
- Next steps:
 - Integrating calibration, more time-integration capability (NukFit?),
 - Reconstruction? Needed?
- Need to design (digital) test objects
 - For absorbed dose calculation (easy)
 - For all steps of the CDW (not so easy...)

For further questions please refer to the gitlab page

(<https://gitlab.com/opensose/opensose3D>) or contact jose.fragoso@inserm.fr

Thank you

EFOMP Special Interest Group on Radionuclide dosimetry



EFOMP

<https://www.efomp.org/index.php?r=pages&id=sigs>