Intermediate ExtravDose Training

utilizing VARSKIN+ (V+) Version 2.0, software release: April 1, 2025

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Training Progression for ExtravDose

Training on theory covers multiphysics mathematical models for fluid flow, activity concentrations, and dosimetry

Beginner training emphasizes Basic calculation

Intermediate training includes Advanced calculation features ← You are here.

ExtravDose discussions

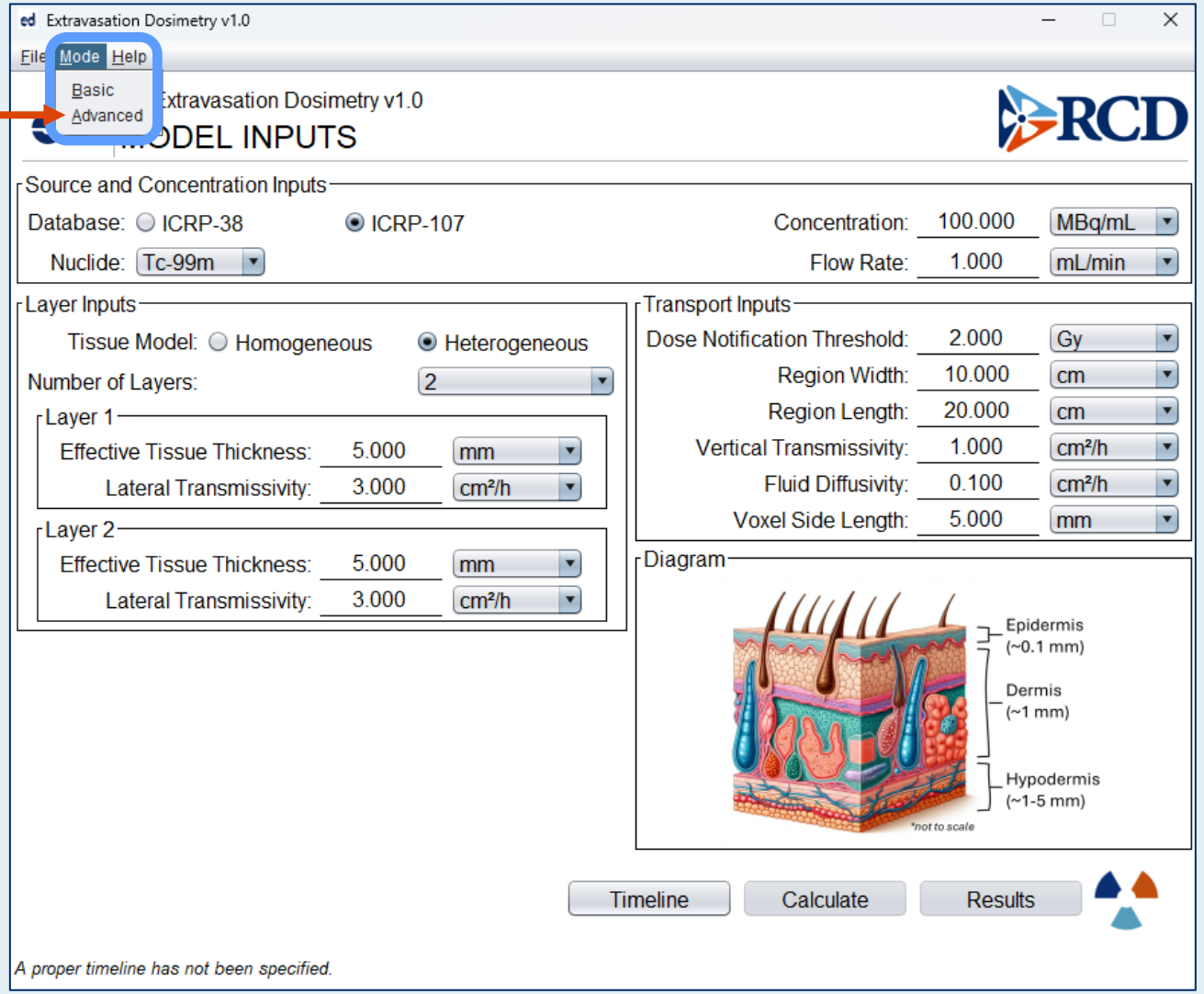
Intermediate Training Outline

1. Advanced Parameters & Buttons
2. Text Reporting & Data Exporting
3. Suggestions for Intermediate Users
4. Numerous Example Calculations
5. Voxel Size Effects
6. Reporting Errors & Posting Questions

1. Advanced Parameters & Buttons

Switching to Advanced Mode

Select Advanced Mode

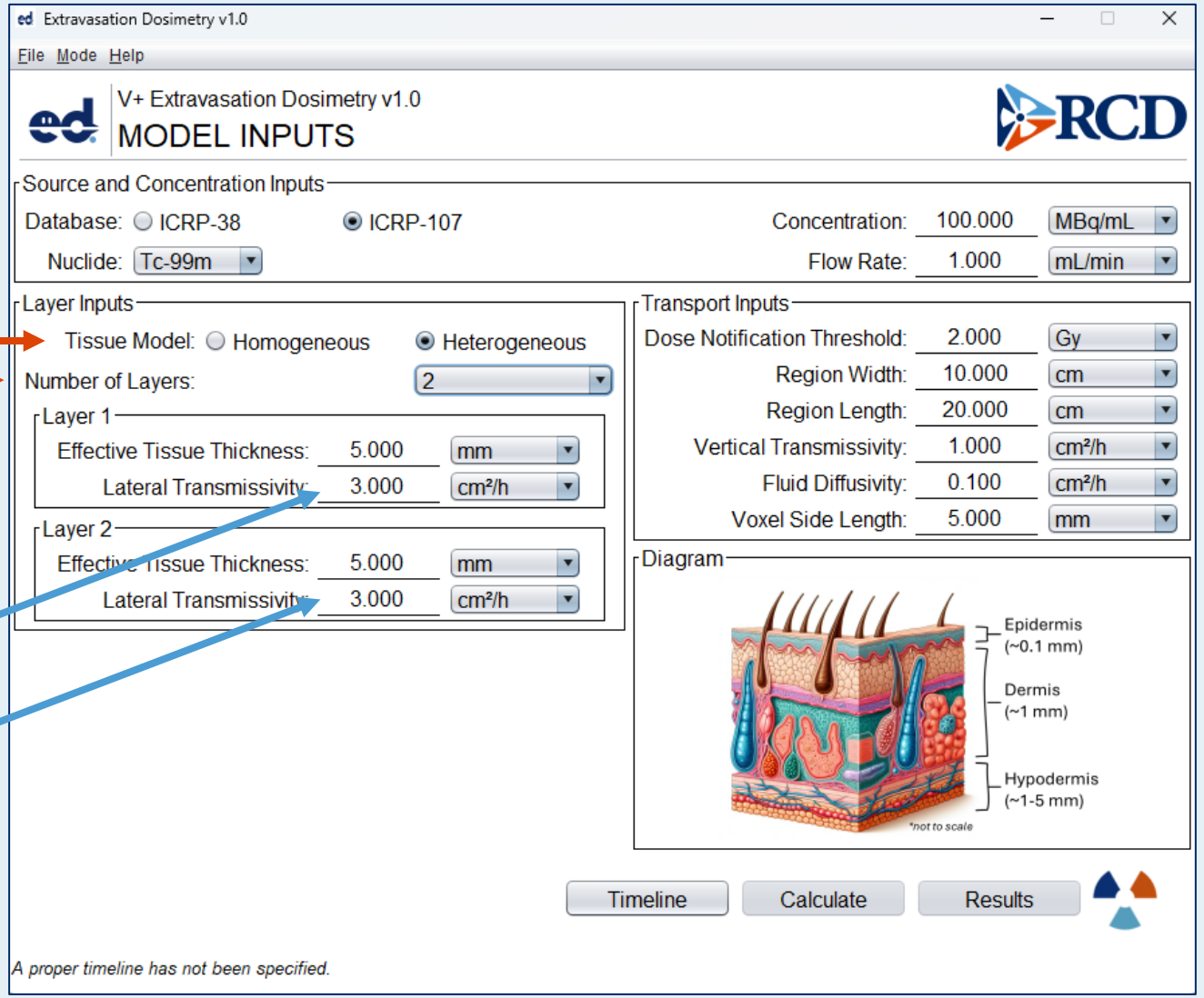


Advanced Layer Inputs

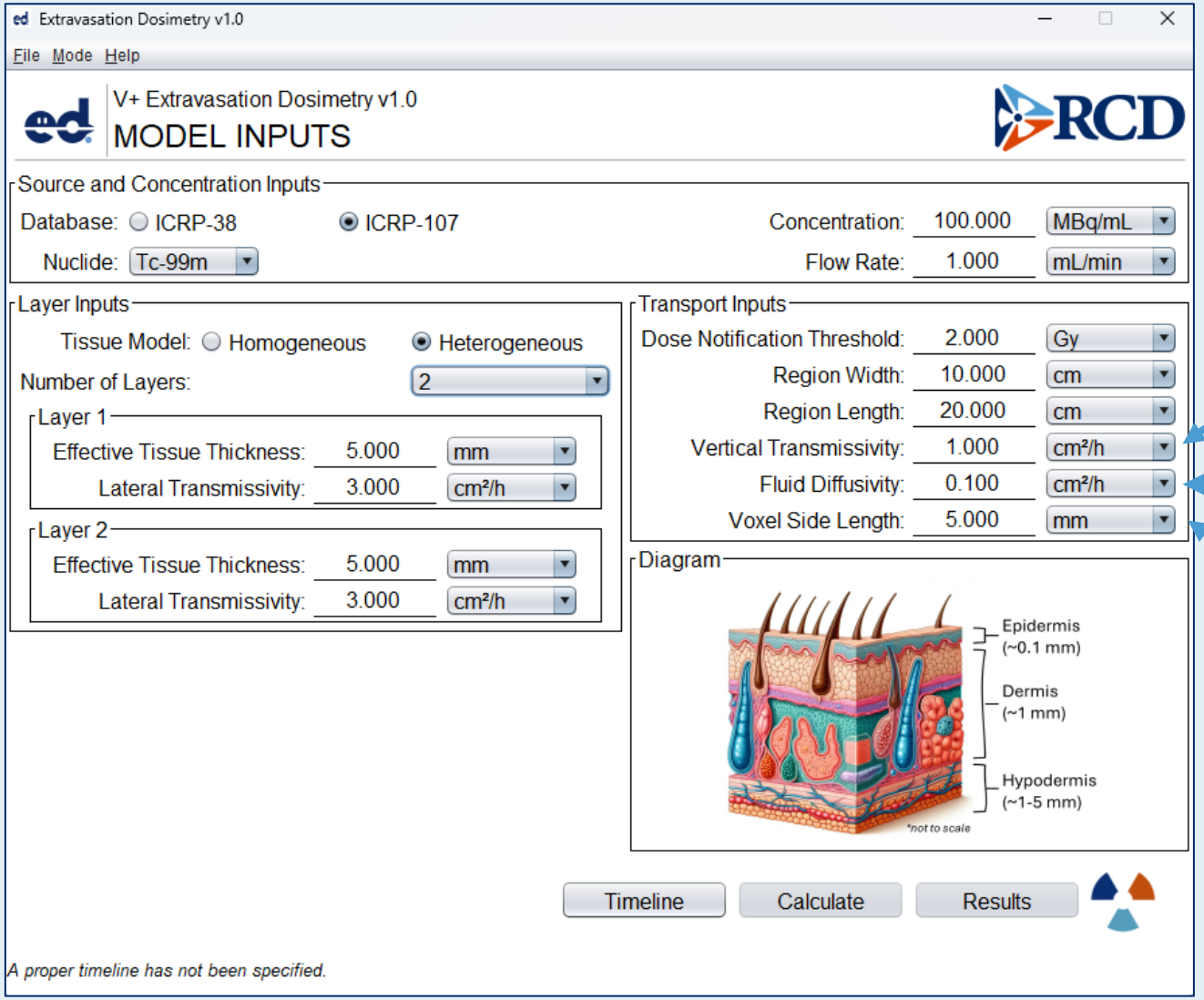
Required for Advanced calculations

Homogeneous or Heterogeneous
Up to 4 layers

Enter Lateral Transmissivity for each layer



Advanced Transport Inputs



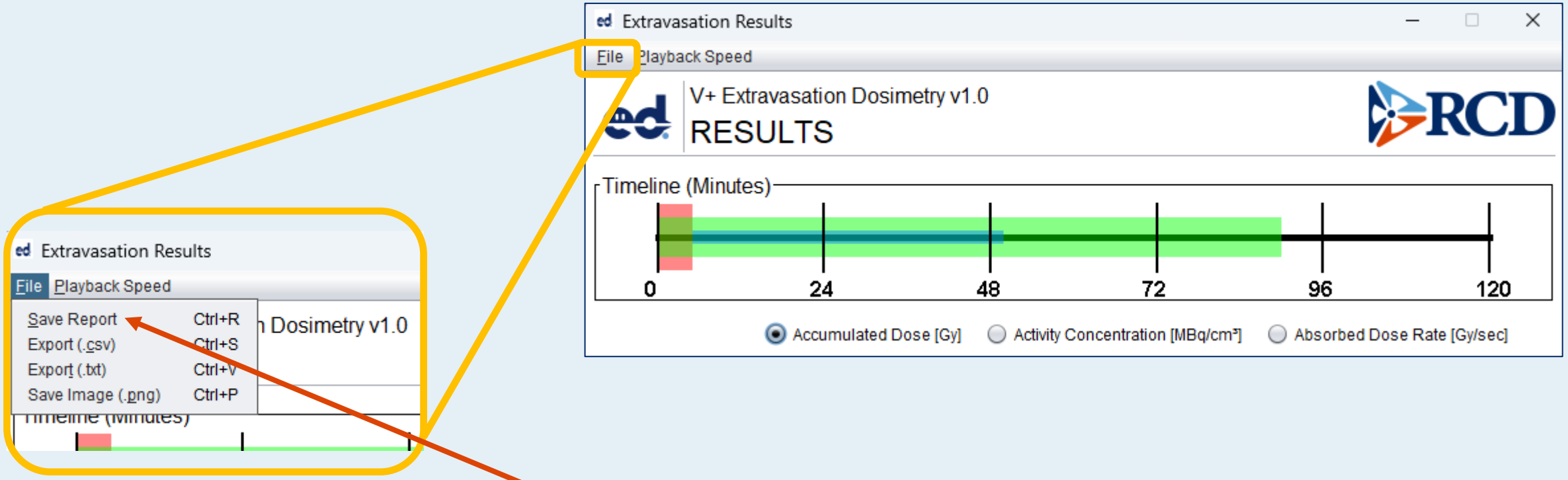
Enter Vertical Transmissibility

Enter Fluid Diffusivity

Enter Voxel Side Length

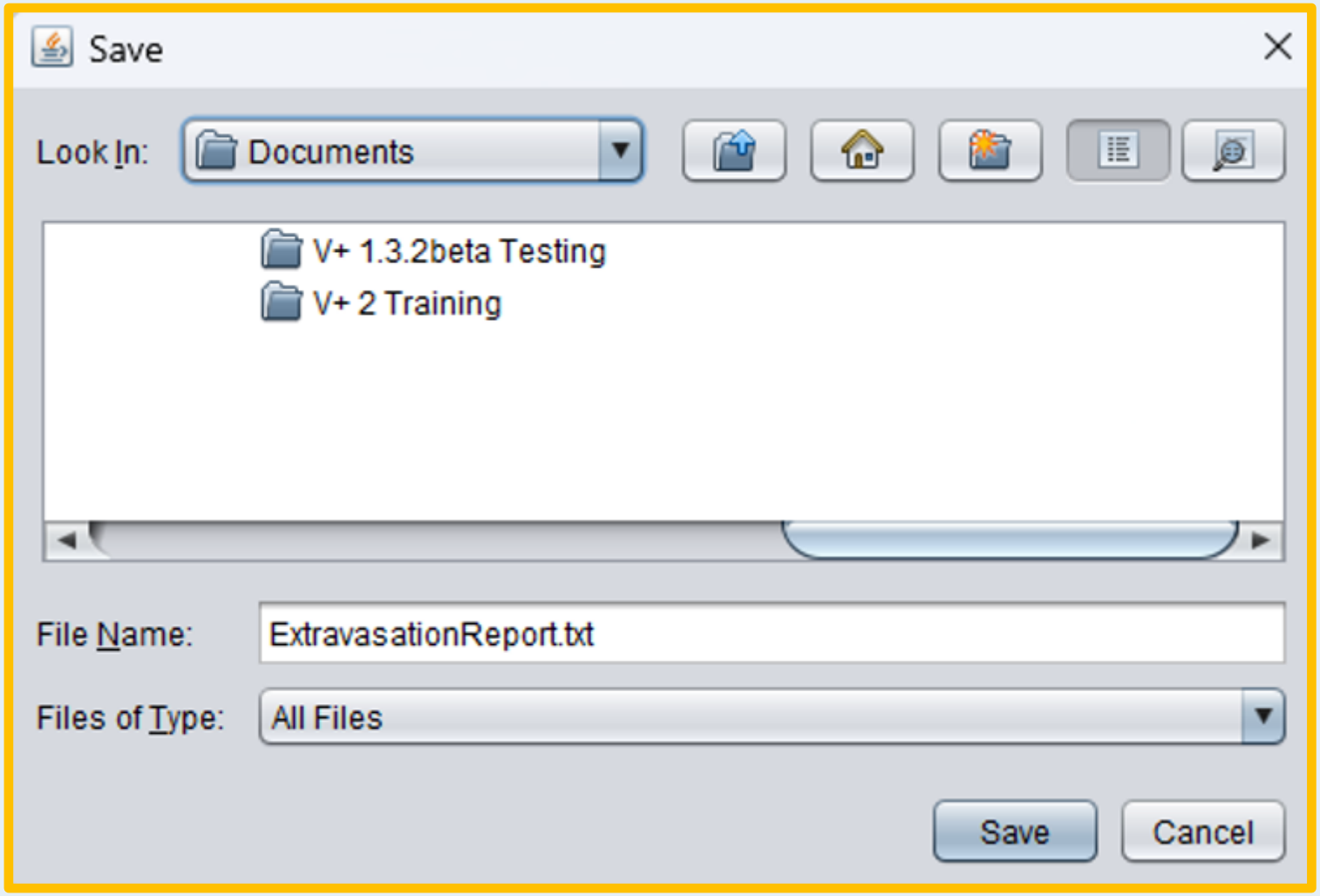
2. Text Reporting & Data Exporting

Saving Text Report



Select Save Report

Save Report before Opening



Default file name is provided

Text Report Overview: Source, Concentration, & Layer User Inputs

```
**********************************************************************************************
User Inputs
**********************************************************************************************


----------------------------------------------------------------------------------------------
Source and Concentration Information
----------------------------------------------------------------------------------------------
                                Database:      ICRP107
                                 Nuclide:          F-18
          Administration Concentration:        370.0     MBq/mL
              Administration Flow Rate:          0.2     mL/min
            Total Extravasated Volume:           1.0        mL
           Total Extravasated Activity:        370.0        MBq

----------------------------------------------------------------------------------------------
Layer Inputs
----------------------------------------------------------------------------------------------
                           Tissue Model: Heterogenous
                         Number of Layers:          3

                      Break Down by Layer

          Effective Tissue Thickness 1:          2.0        mm
              Lateral Transmissivity 1:          2.0      cm²/h

          Effective Tissue Thickness 2:          2.0        mm
              Lateral Transmissivity 2:          2.0      cm²/h

          Effective Tissue Thickness 3:          2.0        mm
              Lateral Transmissivity 3:         0.01      cm²/h
```

Text Report Overview: Transport & Event User Inputs

```
--------------------------------------------------------------------------------
Transport Inputs
--------------------------------------------------------------------------------
   Radiation Dose Notification Threshold:          2.0         Gy
                           Region Width:          2.0         cm
                          Region Length:          2.0         cm
                 Vertical Transmissivity:        0.001      cm²/h
                       Fluid Diffusivity:        0.001      cm²/h
                 Cubic Voxel Side Length:          0.2         cm

--------------------------------------------------------------------------------
Event Inputs
--------------------------------------------------------------------------------
                              Event 1 - Extravasation
                         Event Start Day:            1
                        Event Start Time:        12:00        AM
                           Event End Day:            1
                          Event End Time:        12:05        AM
                          Event Duration:        0.083         h

                              Event 2 - Limb Elevation
                         Event Start Day:            1
                        Event Start Time:        12:05        AM
                           Event End Day:            1
                          Event End Time:        12:50        AM
                          Event Duration:        0.750         h
                          Lift Elevation:          0.0    degrees
    Pull Angle (Polar Location of Lift):         90.0    degrees

                             Event 3 - Analysis Period
                         Event Start Day:            1
                        Event Start Time:        12:00        AM
                           Event End Day:            1
                          Event End Time:        01:30        AM
                          Event Duration:        1.500         h
```

Limb remains flat – No elevation (Lift angle = 0.0 degrees)

Text Report Overview: Numerical Outputs

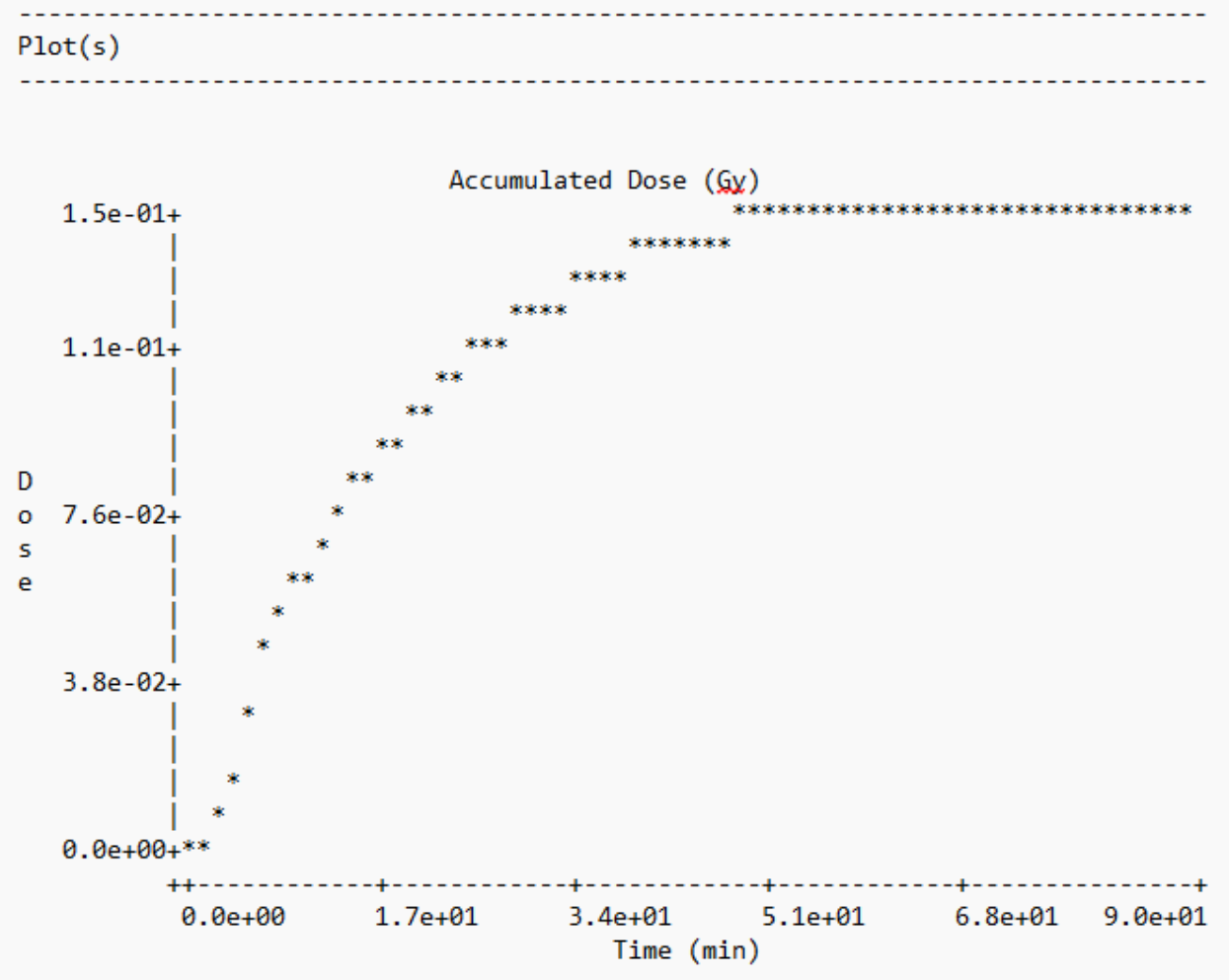
```
**********************************************************************************************
Outputs
**********************************************************************************************
                                Max Voxel Dose:      3.84e-01          Gy
                            Max Voxel Dose Rate:     8.51e-04          Gy/s
                        Time to Max Voxel Dose Rate:      5.0          min
                    ROI Exceeding Dose Threshold:        0.0           %
                                Dose to ROI:         1.52e-01          Gy
                                Region Volume:           2.4          cm³
```

On-Screen Summary Results

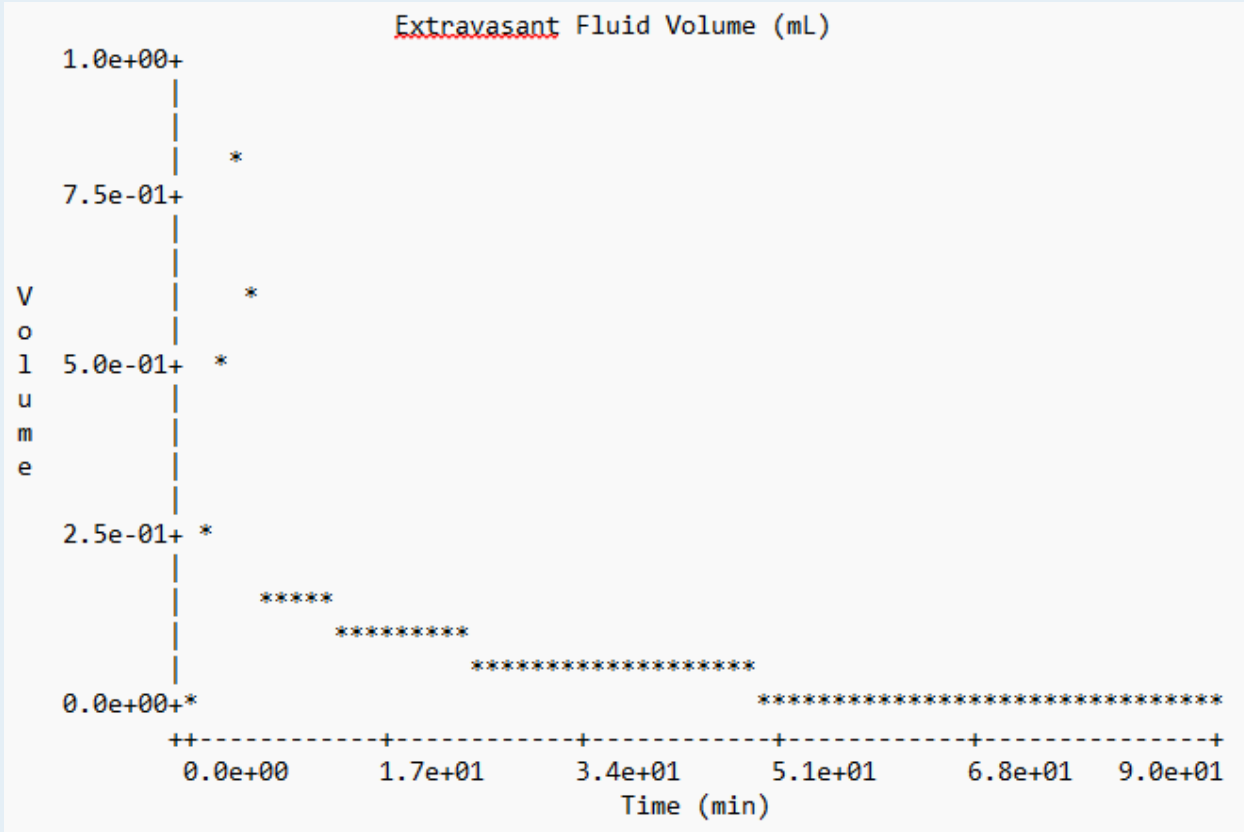
Extravasated Activity:	3.70e+02	MBq
Extravasated Volume:	1.00e+00	mL
Maximum Voxel Dose:	3.84e-01	Gy
Maximum Voxel Dose Rate:	8.51e-04	Gy/sec
Time to Maximum Voxel Dose Rate:	5.00	min
ROI Exceeding Threshold (2.0 Gy):	0.00	%
Dose to ROI:	1.52e-01	Gy

Text Report Overview: Output Plots for …

Accumulated Dose

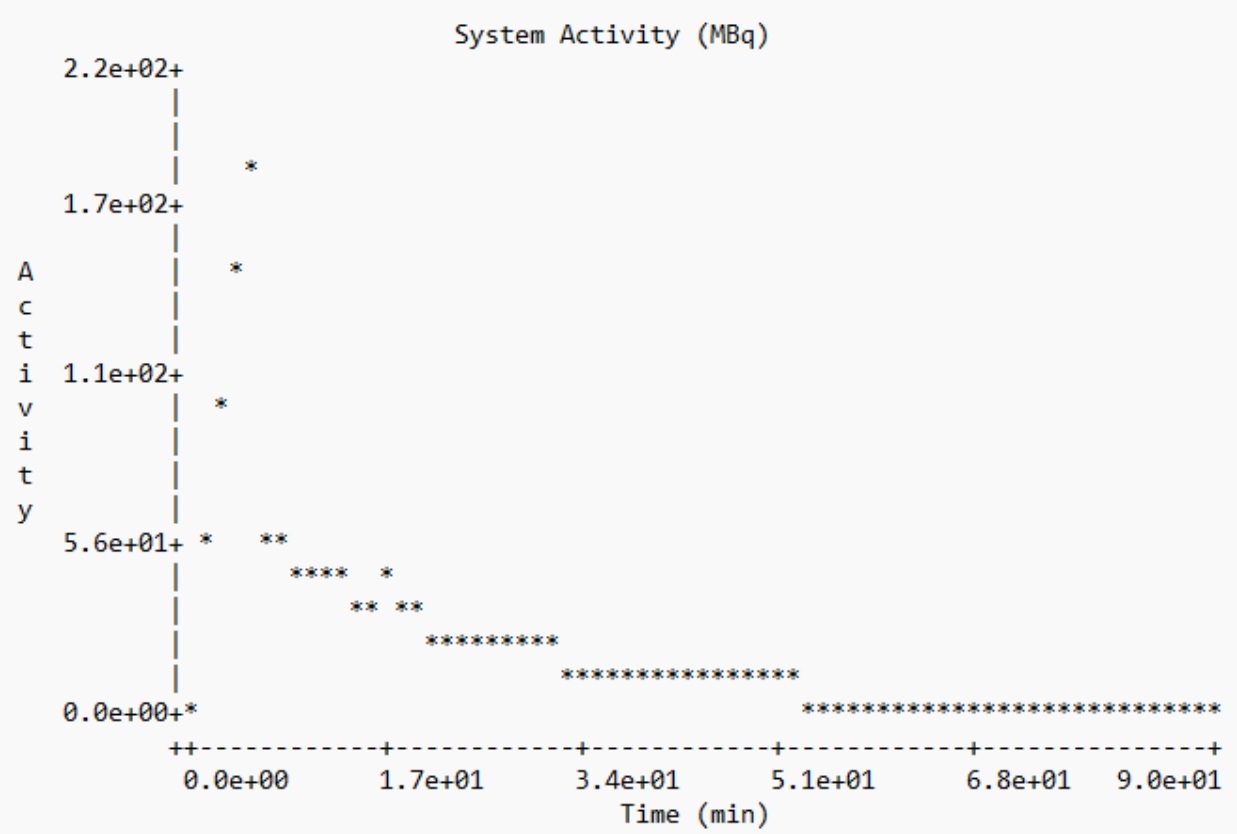


Extravasated Fluid Volume in Tissue Region

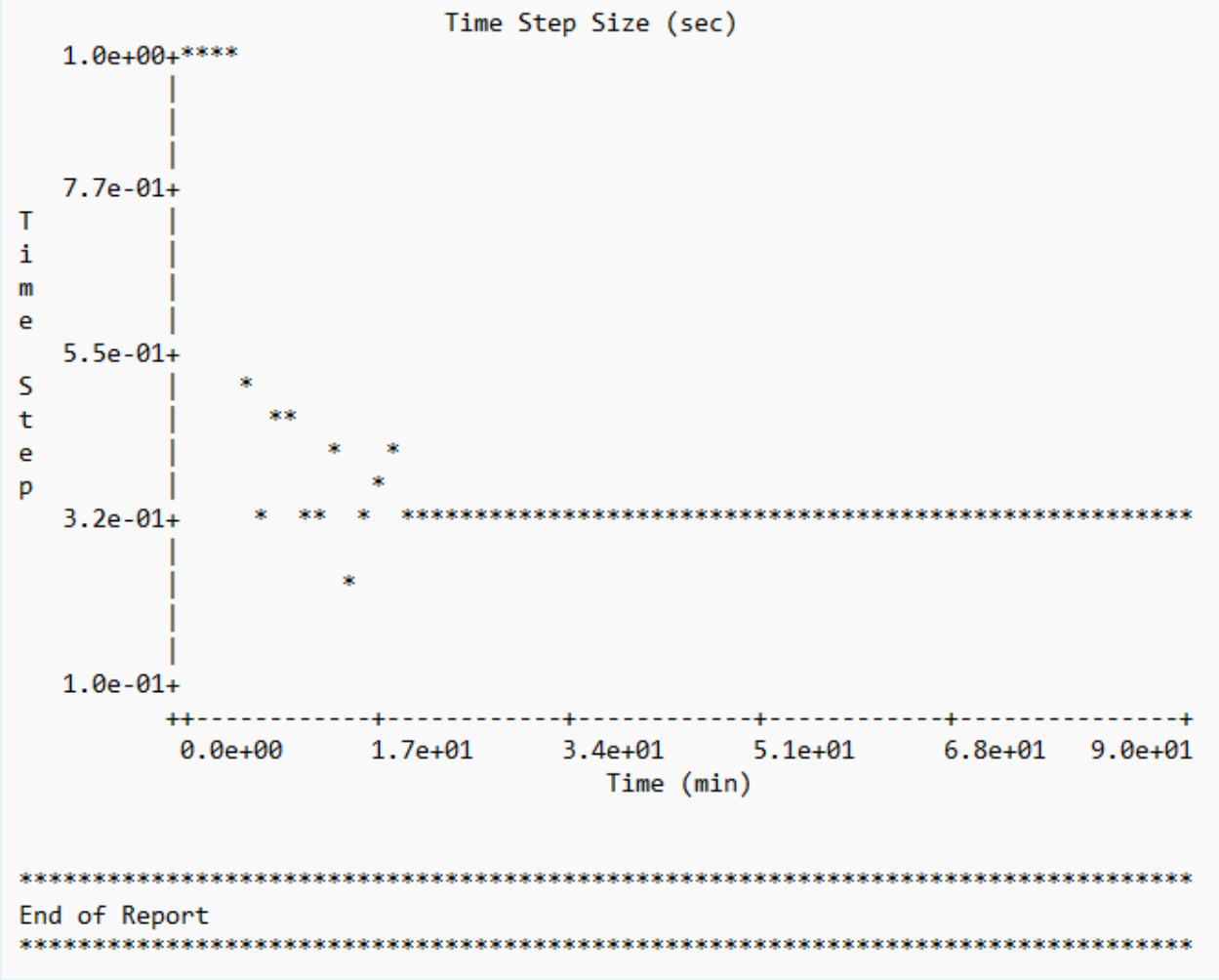


Text Report Overview: Additional Output Plots for …

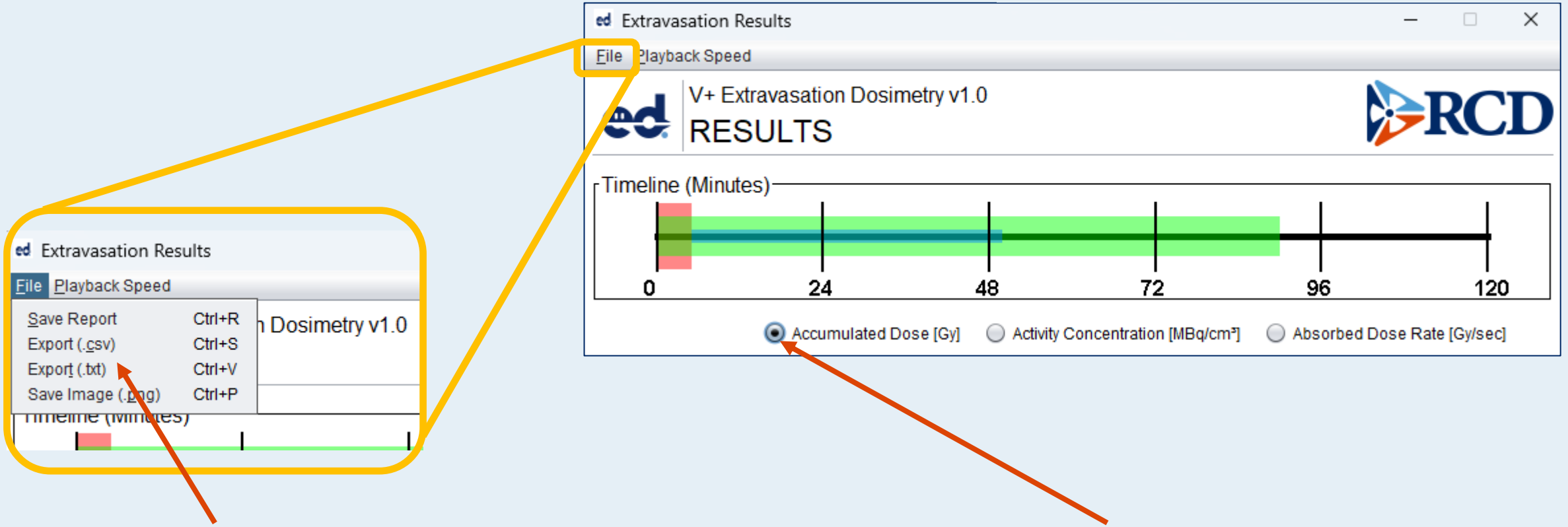
Activity in the Tissue Region of Interest



Simulation Time Step Size

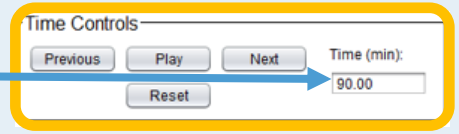


Exporting Data



Select Export (.csv) or Export (.txt) to save voxel results for Accumulated Dose.

Results are exported for a specific time step.



3. Suggestions for Intermediate Users

Suggestions on approaching advanced calculations

User interface is flexible; users encouraged to gradually add complexity or increase computational size

1. Determine *Effective Tissue Thickness* infiltrated by extravasated radioactive fluid
2. Select smallest *Region Length* & *Region Width* for the calculation and slowly increase dimensions until the maximum voxel dose no longer increases (i.e., confirms negligible boundary effects on max voxel dose)
3. Begin with largest *Voxel Side Length* consistent with three dimensions above
4. Consider adjusting dimensions slightly to find largest *Voxel Side Length* suitable for the problem

   Note: Transmissivity values are applied at the voxel level (not layer or full thickness levels)
5. Review outputs for baseline calculations & identify most-important outputs for the calculation
6. Gradually introduce complexity, preferably only when available information supports it

   • Add tissue layers • Reduce voxel side length • Adjust parameter values for new computational grid
7. Review outputs for added complexity, highlighting strong influences on most-important outputs
8. Compare calculation insights to clinical information (e.g., similar infiltrated tissue dimensions & time frames)

4. Numerous Example Calculations

Example I: Multiple tissue layers

Example I: Advanced calculation for ^{18}F with multiple tissue layers

Slow leakage into surrounding tissue followed by limb elevation for 45 min

Extravasation Dosimetry v1.0

File Mode Help

V+ Extravasation Dosimetry v1.0

MODEL INPUTS

Source and Concentration Inputs

Database: ICRP-38 ICRP-107

Nuclide: F-18

Concentration: 370.000 MBq/mL

Flow Rate: 0.200 mL/min

Layer Inputs

Tissue Model: Homogeneous Heterogeneous

Number of Layers: 3

Layer 1

Effective Tissue Thickness: 2.000 mm

Lateral Transmissivity: 2 cm²/h

Layer 2

Effective Tissue Thickness: 2.000 mm

Lateral Transmissivity: 2 cm²/h

Layer 3

Effective Tissue Thickness: 2.000 mm

Lateral Transmissivity: 0.010 cm²/h

Transport Inputs

Dose Notification Threshold: 2.000 Gy

Region Width: 2.000 cm

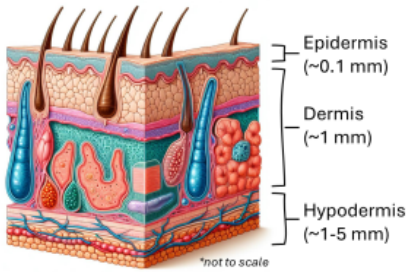
Region Length: 2.000 cm

Vertical Transmissivity: 0.001 cm²/h

Fluid Diffusivity: 0.001 cm²/h

Voxel Side Length: 0.200 cm

Diagram



Timeline Calculate Results

Extravasation Timeline

V+ Extravasation Dosimetry v1.0

EVENT INPUTS

#	Event	Day	Start Time	End Time	Duration (hr)
1	Extravasation	1	12:00AM	12:05AM	0.08
2	Limb Elevation	1	12:05AM	12:50AM	0.75
3	Analysis Period	1	12:00AM	01:30AM	1.50

Add/Delete Events

Add Event Delete Selected Event

Edit Selected Event (#2)

Type: Limb Elevation

Day

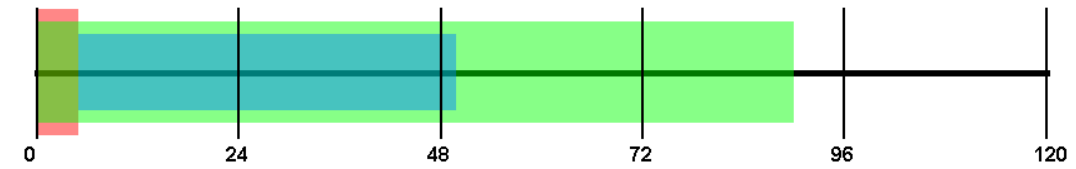
Start Time: 12:05 AM 1

End Time: 12:50 AM 1

Duration: 0.75 Hours

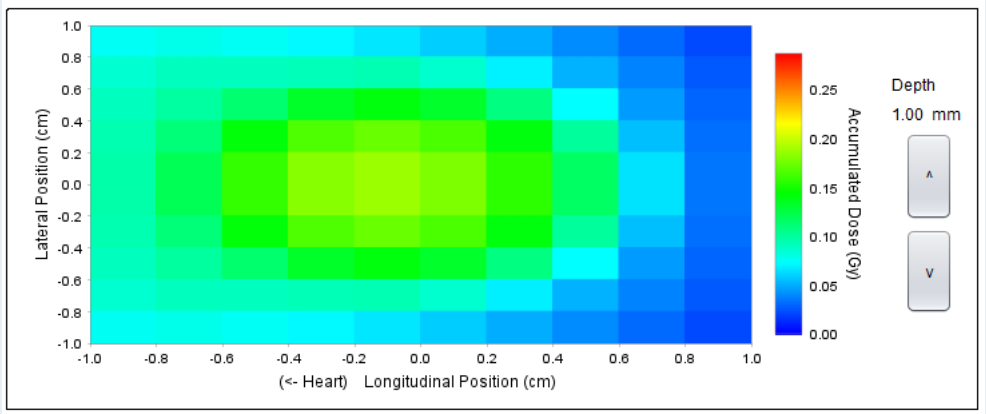
Elevation: 70.0 Degrees

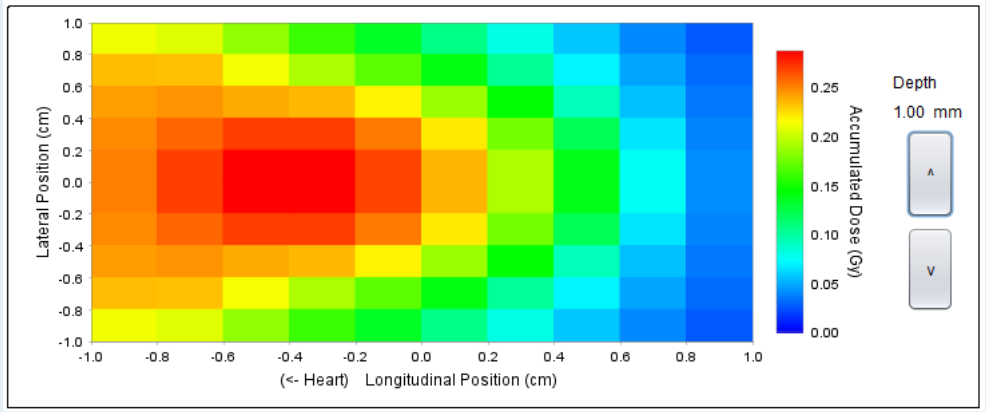
Timeline (Minutes)



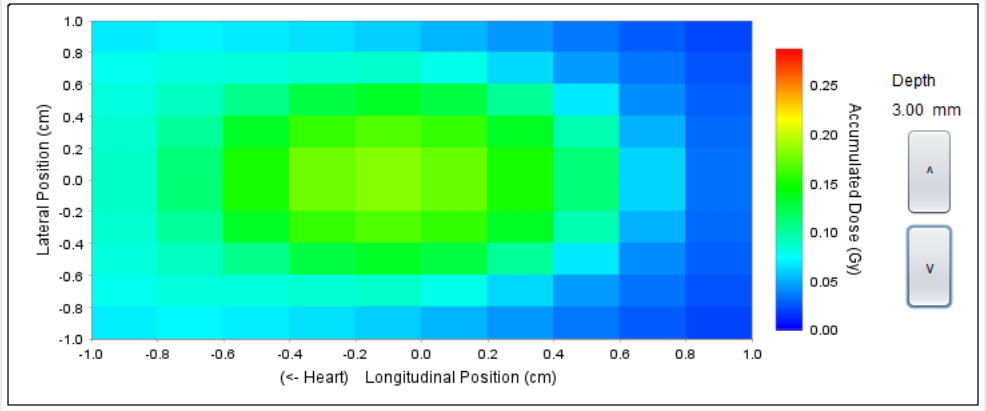
Ex. I: Accumulated doses (Gy) 15 min Elevated end 90 min Elevated end

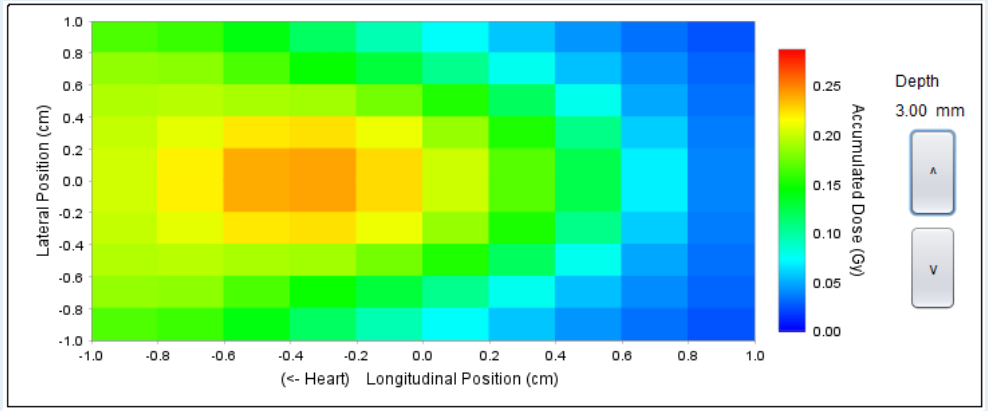
Top 2 mm



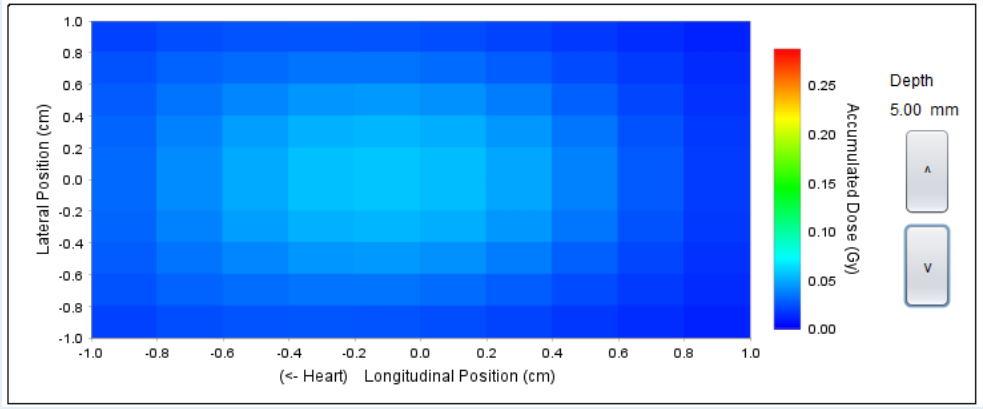


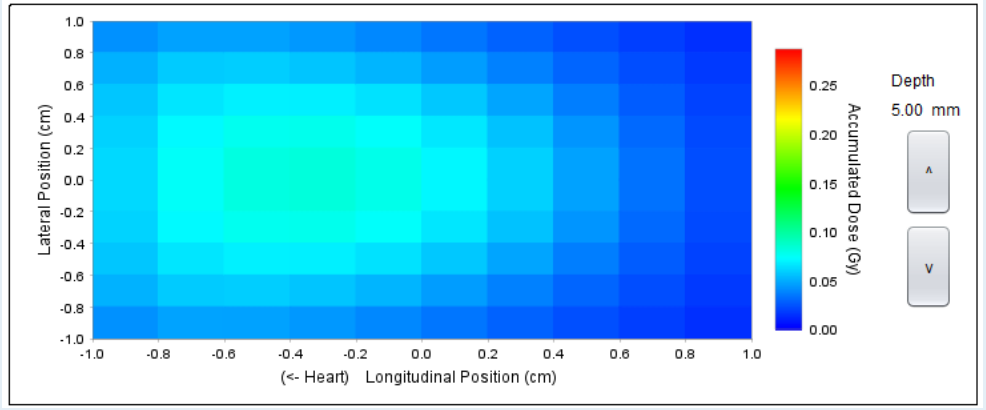
Middle 2 mm





Bottom 2 mm

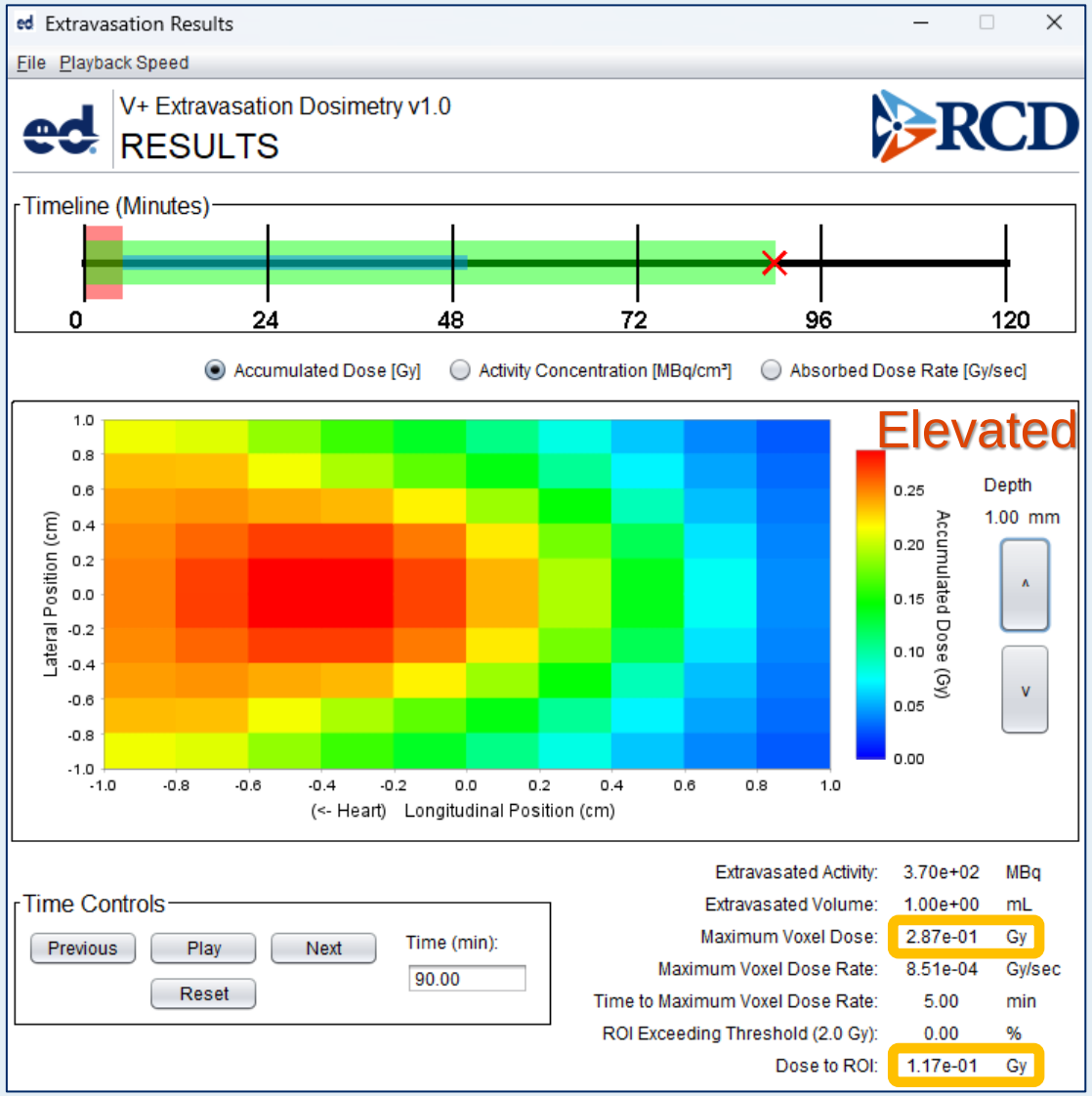




V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/

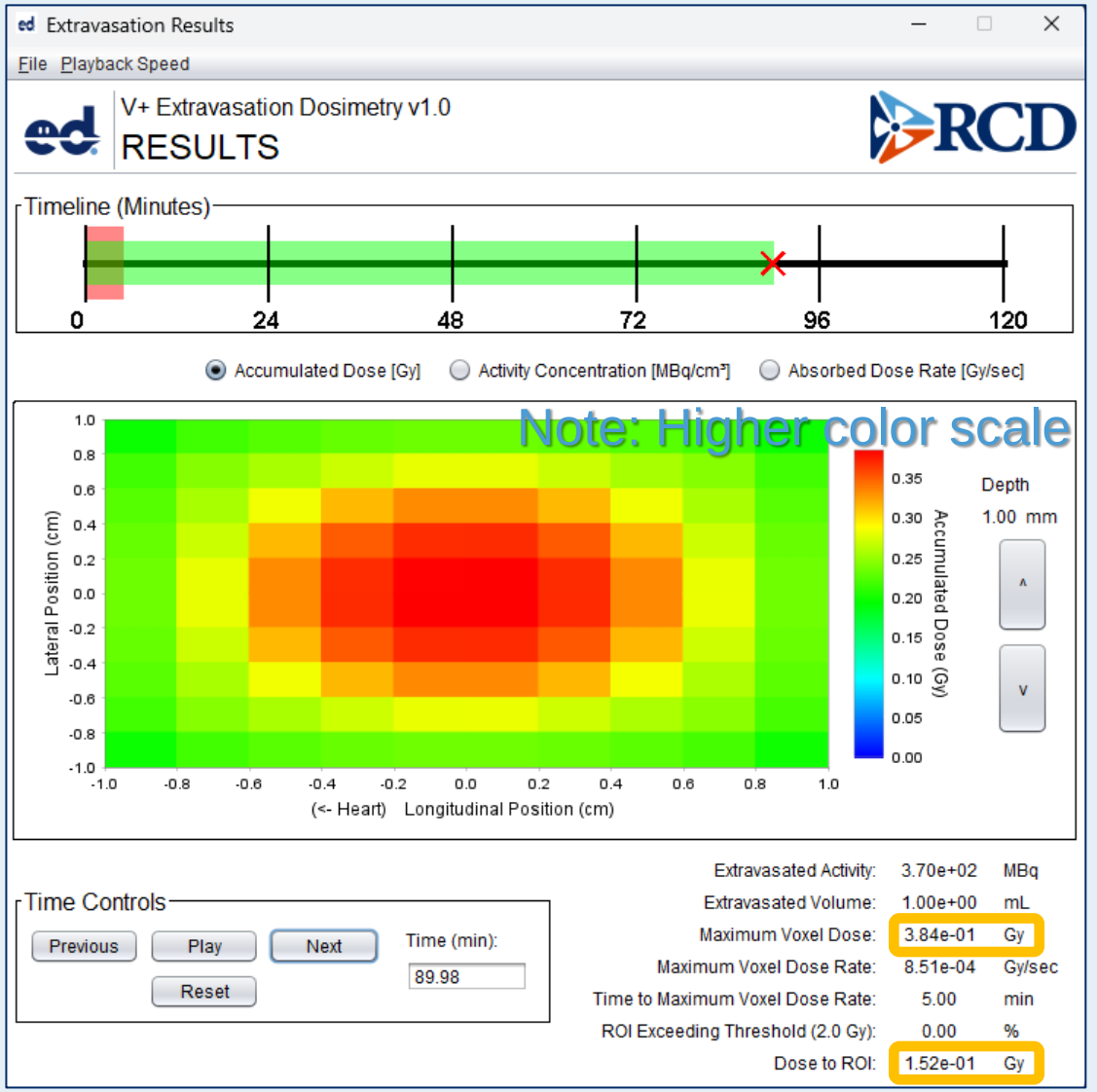
Ex. I: Influence of limb elevation on accumulated doses (Gy)

Elevated limb



Elevated end

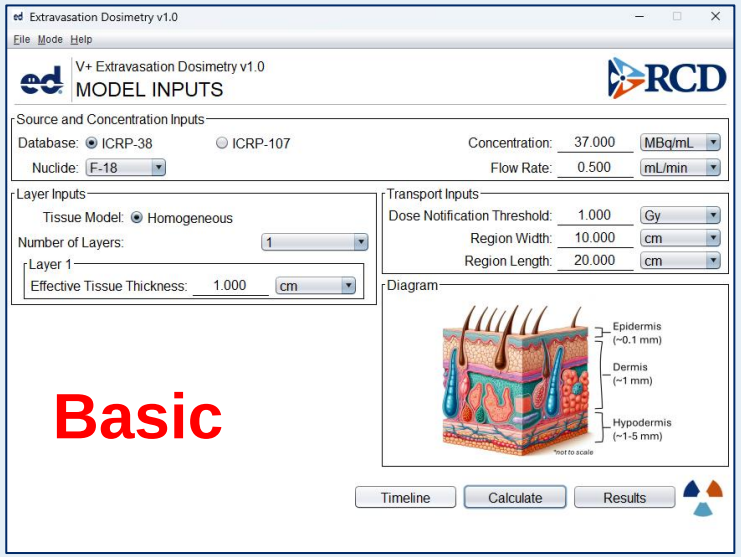
Limb remains flat – No elevation

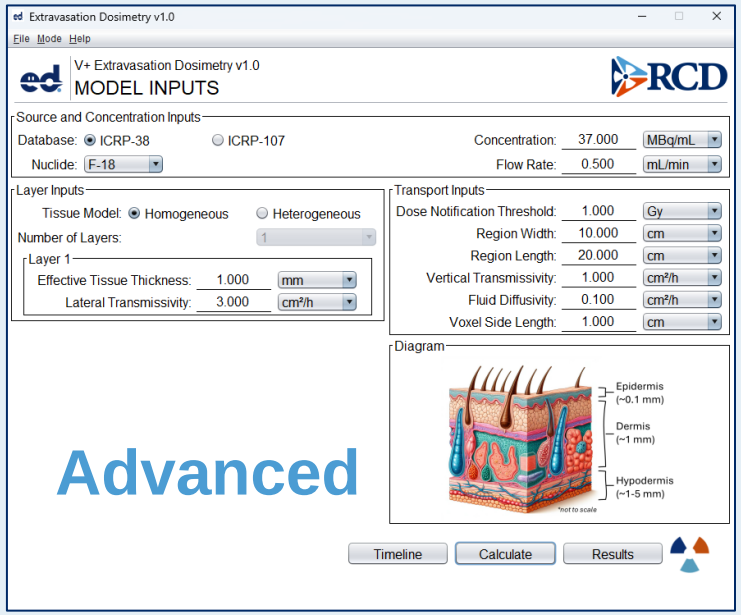


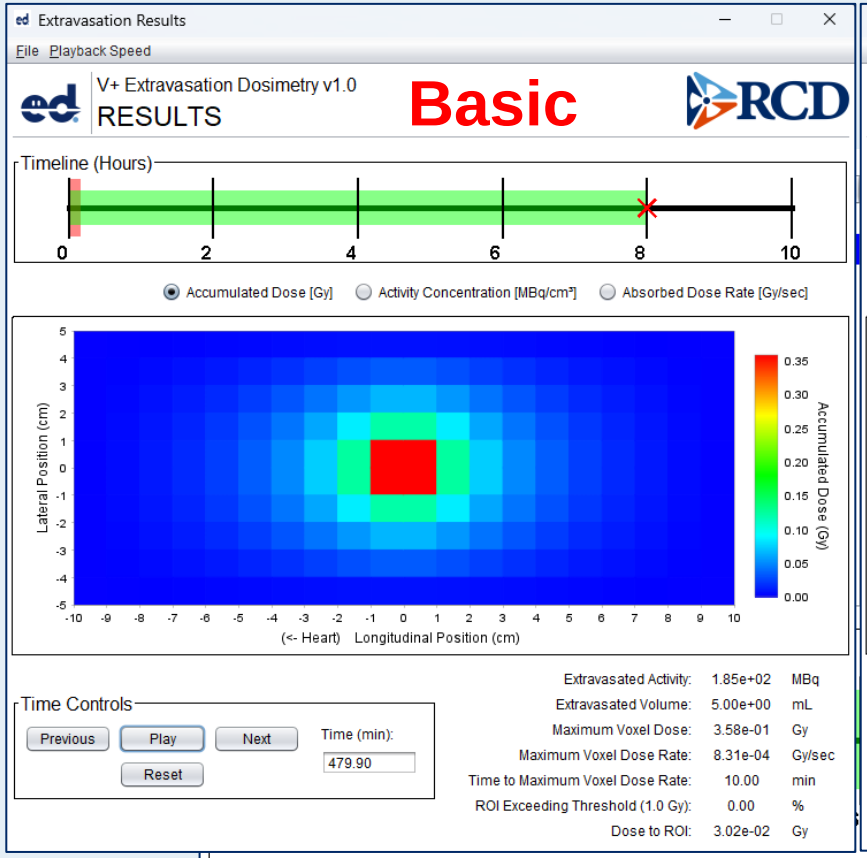
Note: Higher color scale

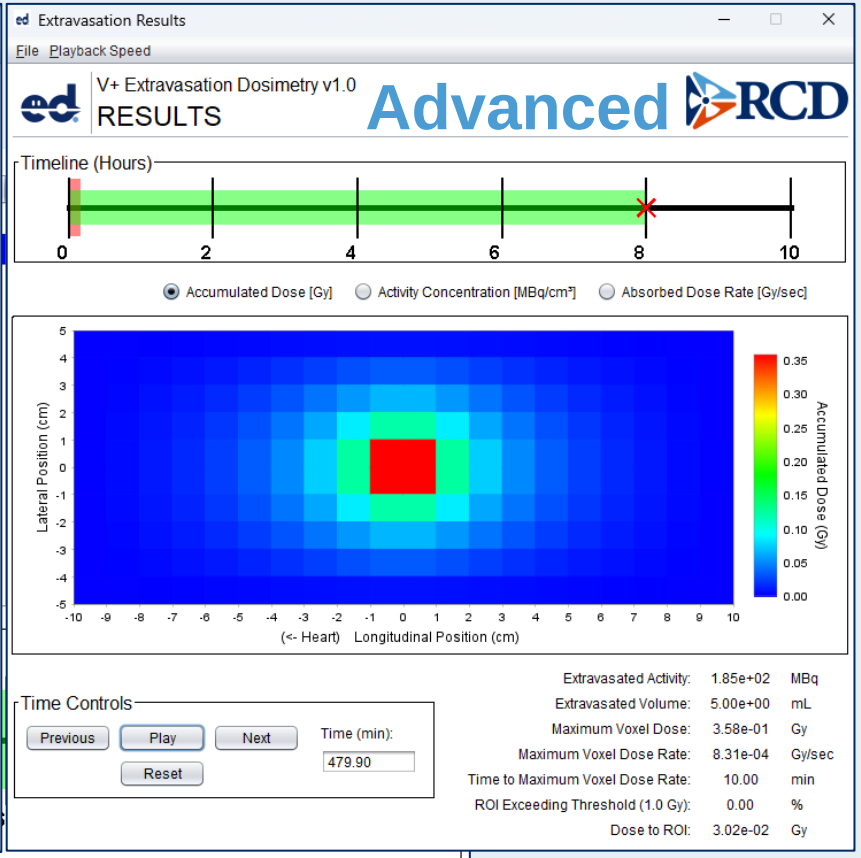
Example II: Basic & Advanced comparison

Example II: Switching Basic→Advanced calculation yields same results



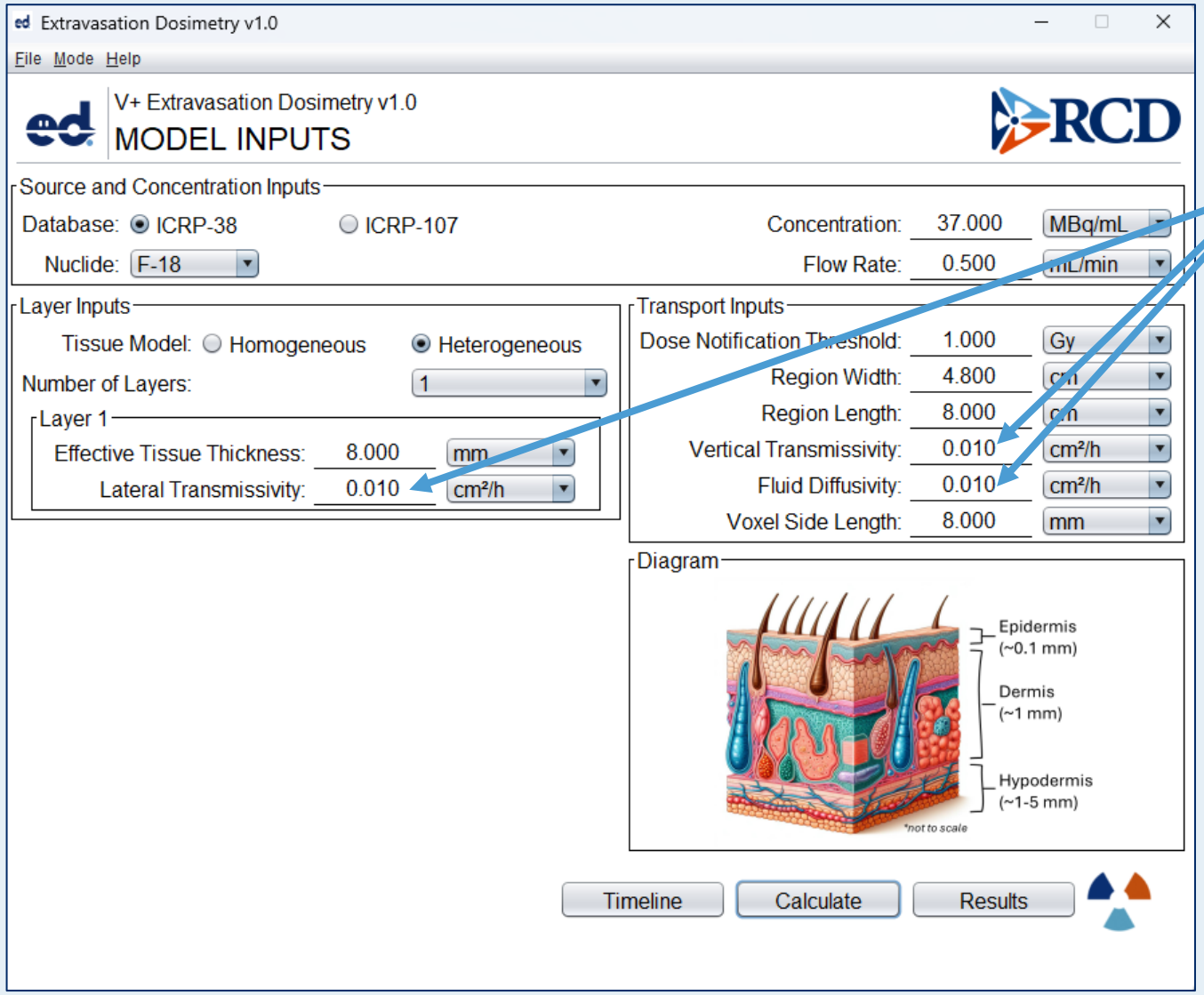






Example III: Trapped fluid (special case)

Example III input: Trapped fluid (special case)

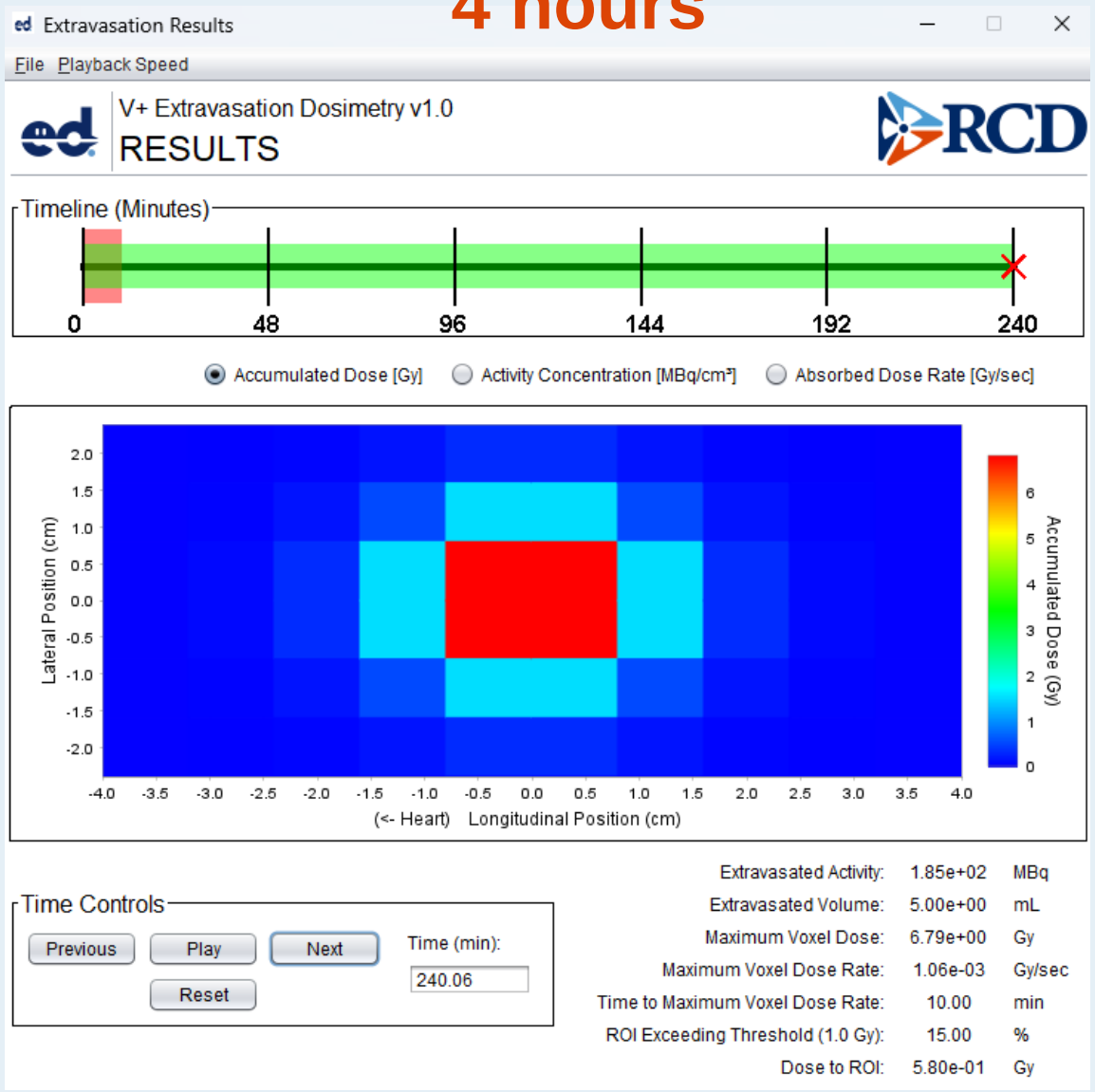


Small values for transmissivity & diffusivity

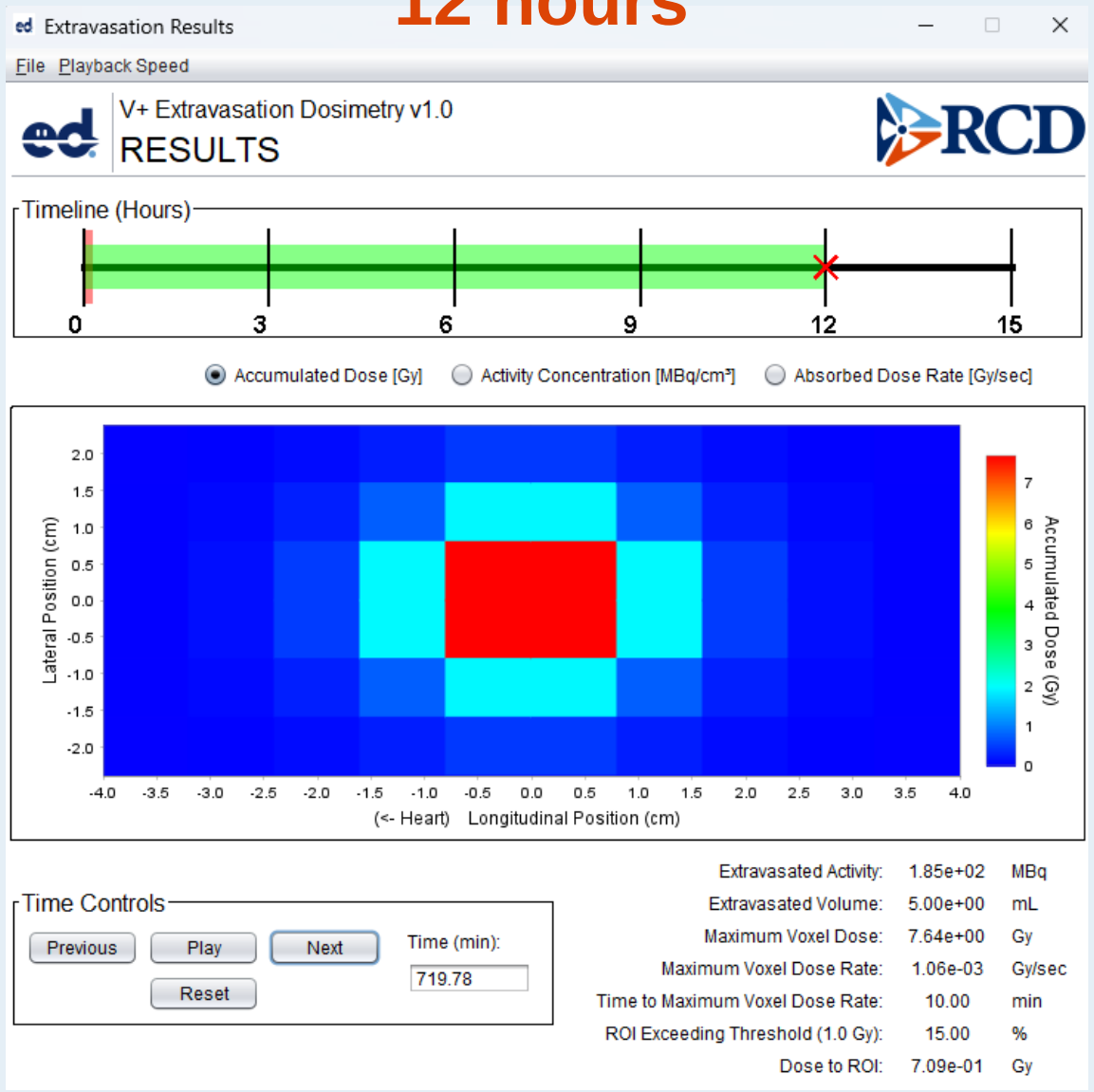
Compare results for different analysis times (next slide)

Example III results for different analysis times

4 hours

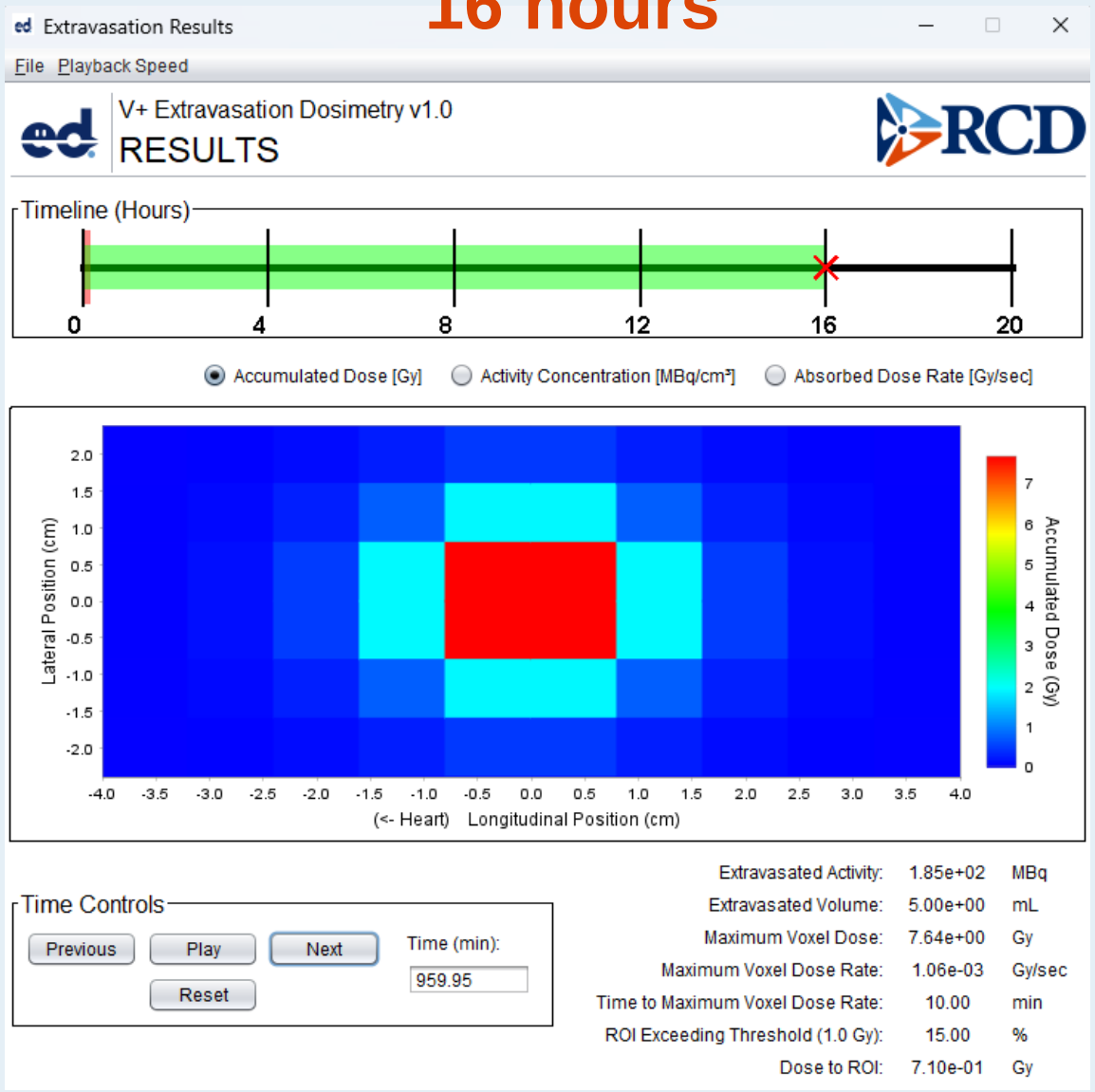


12 hours

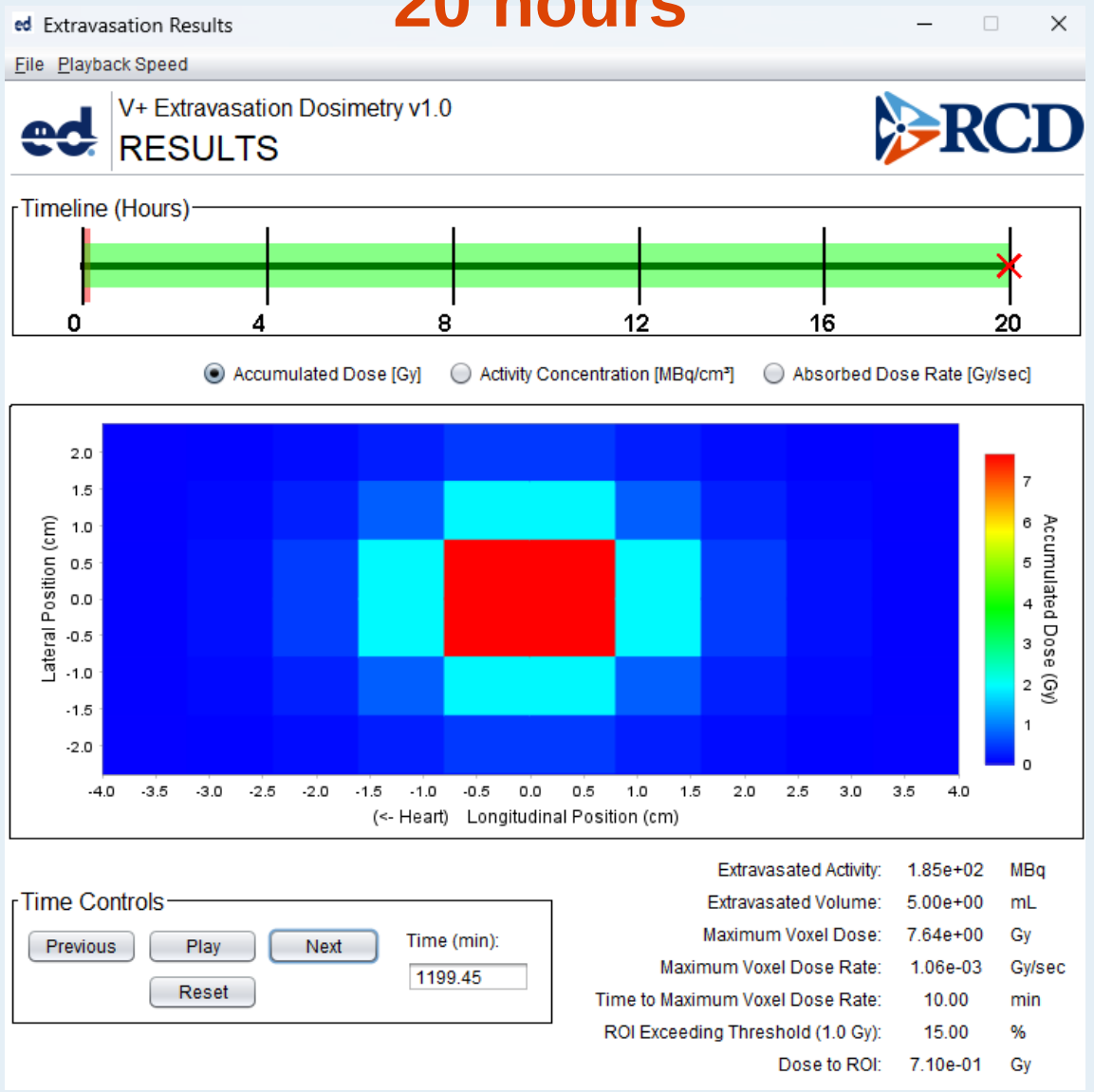


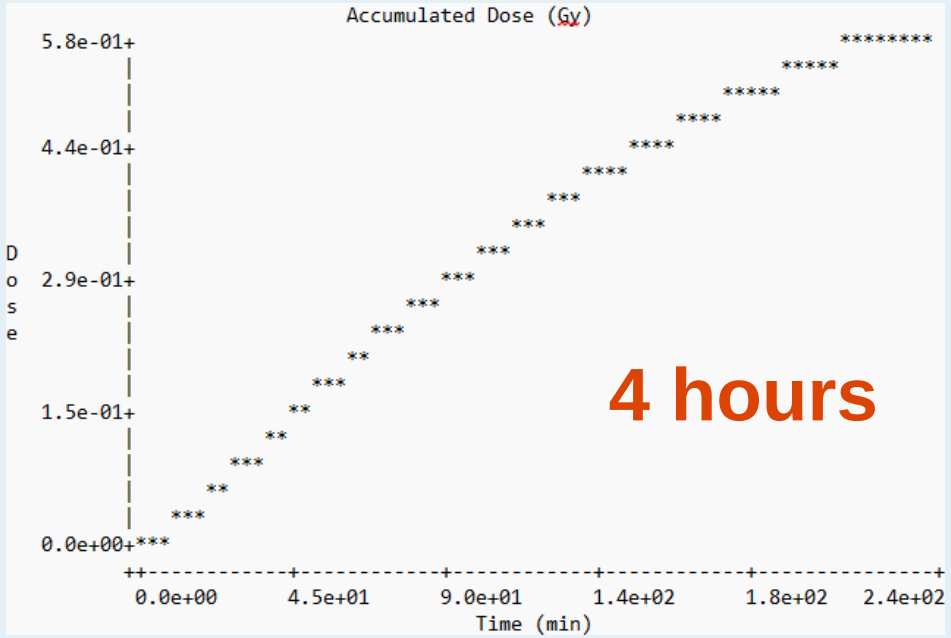
Example III results for different analysis times (cont'd)

16 hours

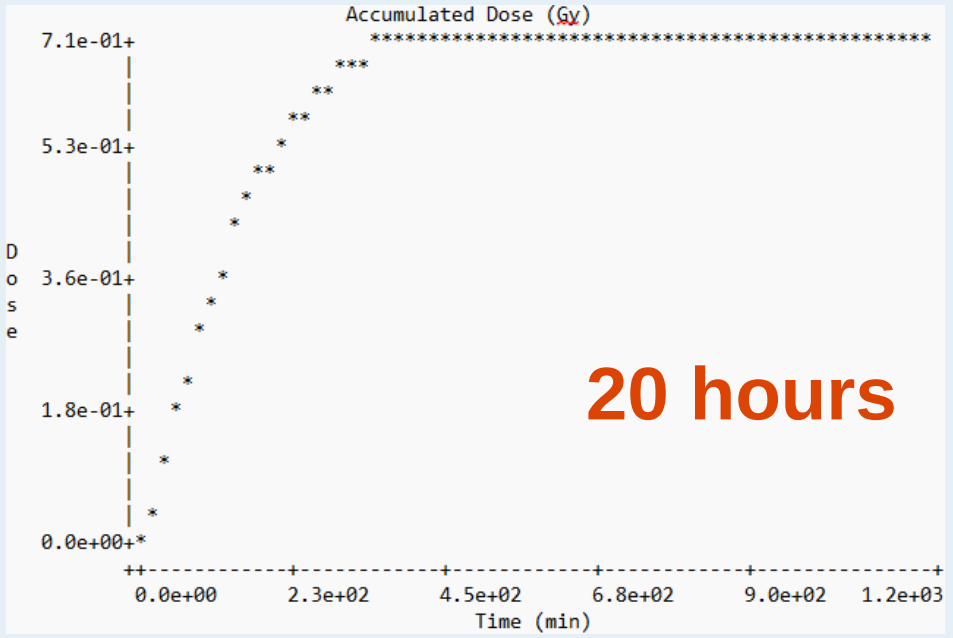


20 hours

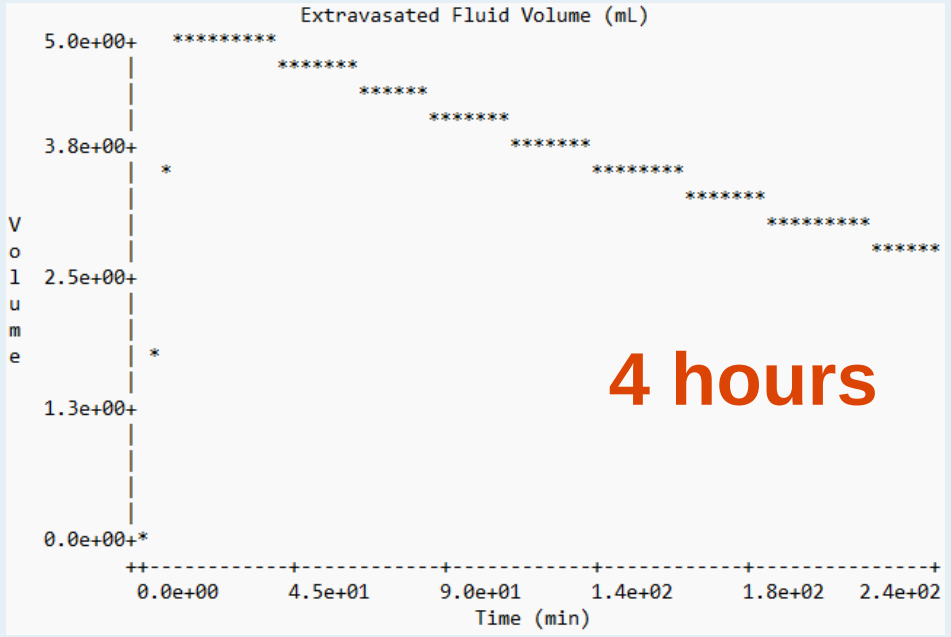




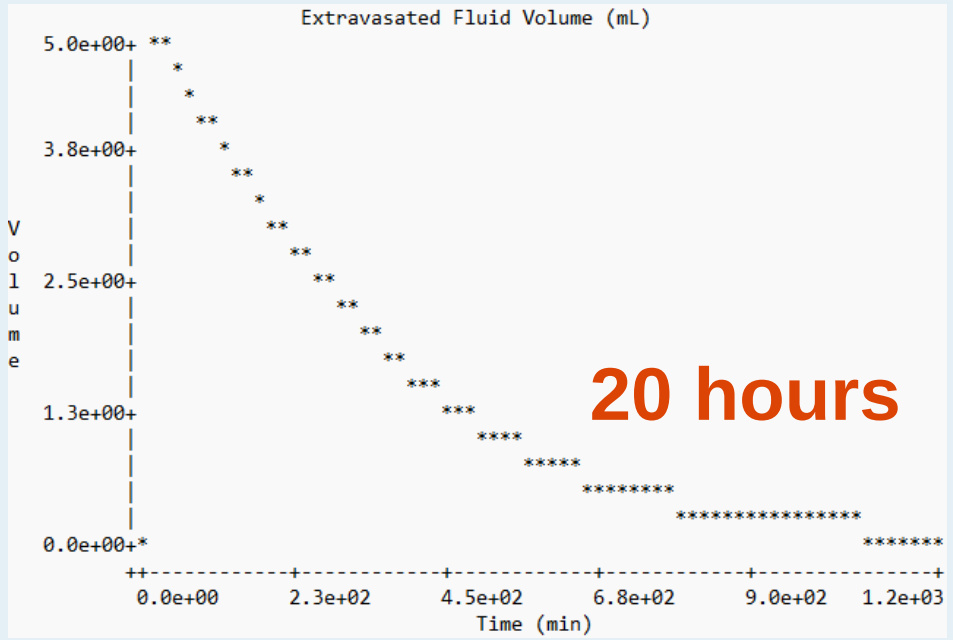
4 hours



20 hours



4 hours



20 hours

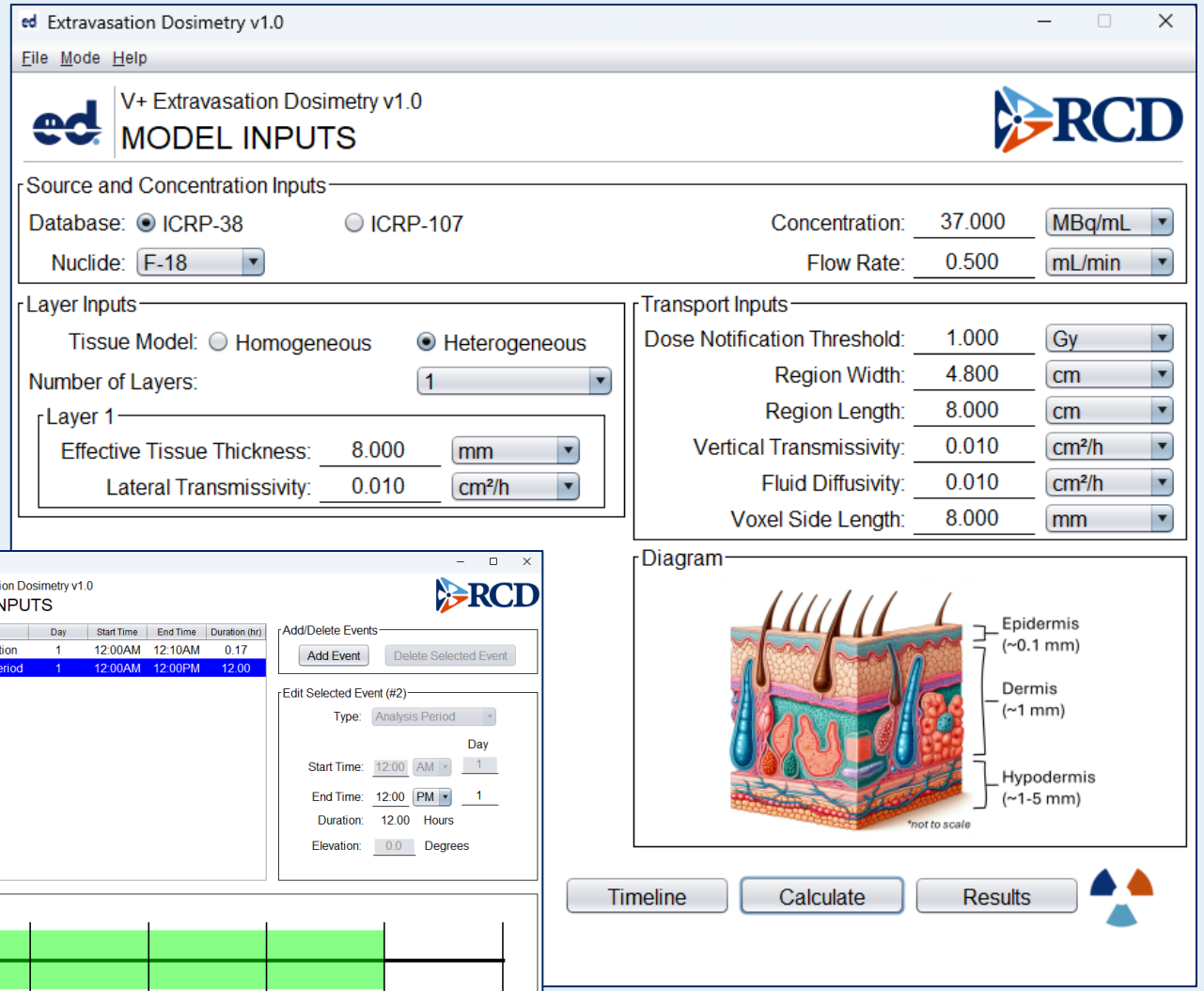
Example III report plots

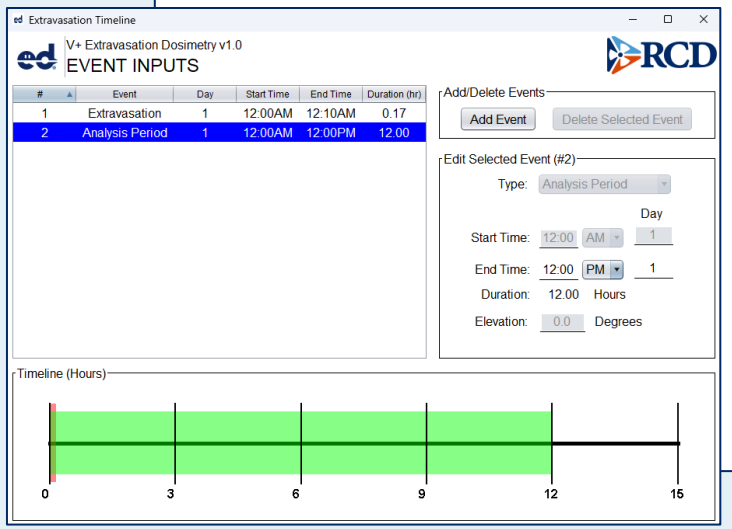
V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/

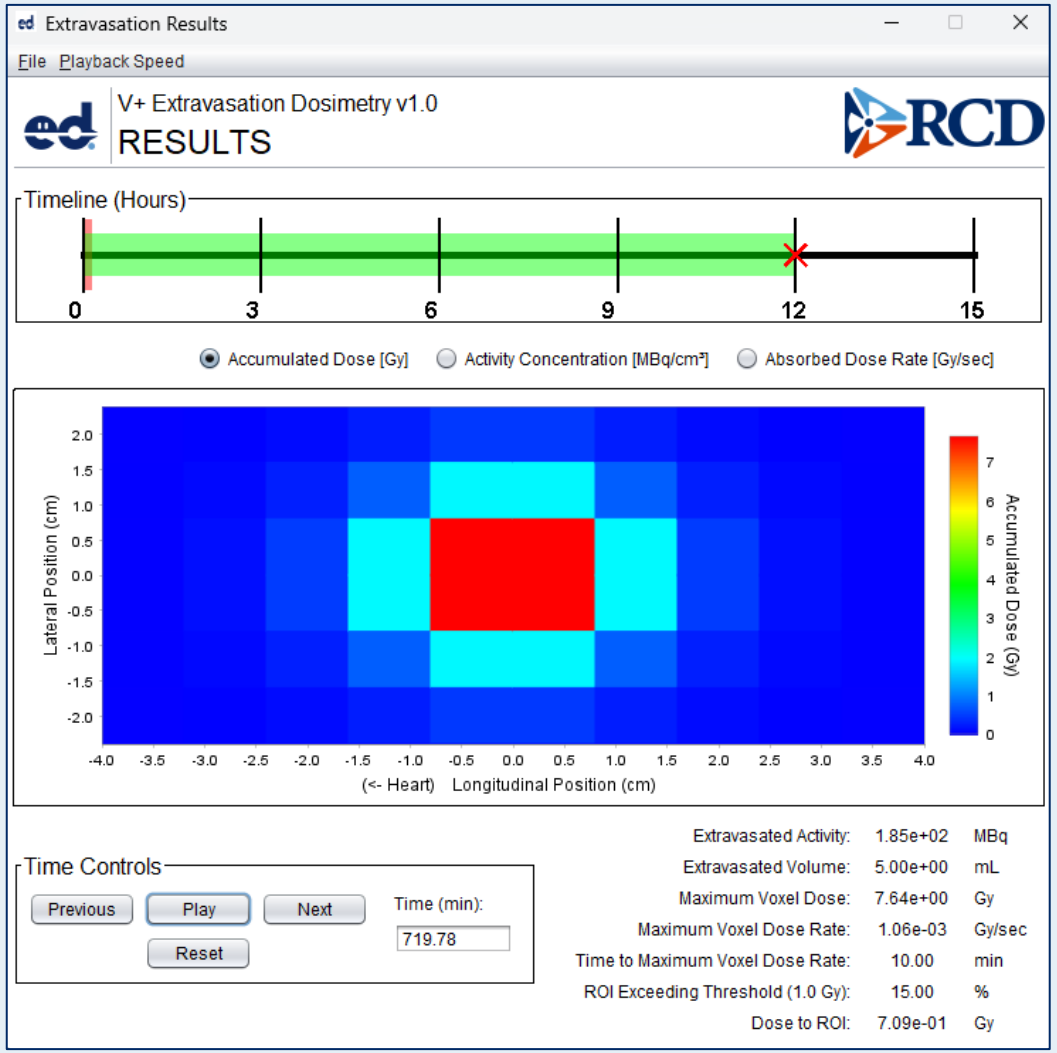
Example IV: Parameter memory

- **Explanation of current behavior**
- **V+ comment added to issue tracker**

Example VI builds on Example III (Advanced Calculation)







Parameter Memory Demonstrated

Advanced Calculation switched to Basic Calculation

Extravasation Dosimetry v1.0

File Mode Help

V+ Extravasation Dosimetry v1.0

MODEL INPUTS

Source and Concentration Inputs

Database: ICRP-38 ICRP-107

Nuclide: F-18

Concentration: 37.000 MBq/mL

Flow Rate: 0.500 mL/min

Layer Inputs

Tissue Model: Homogeneous

Number of Layers: 1

Layer 1

Effective Tissue Thickness: 8.000 mm

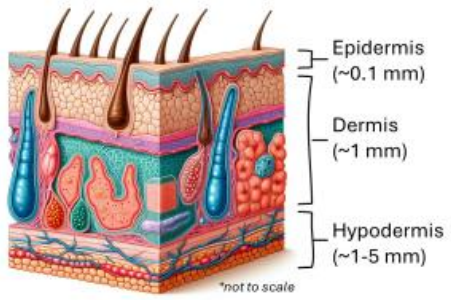
Transport Inputs

Dose Notification Threshold: 1.000 Gy

Region Width: 4.800 cm

Region Length: 8.000 cm

Diagram



Timeline | Calculate | Results

Basic Calculation after Advanced Calculation includes Parameter Memory

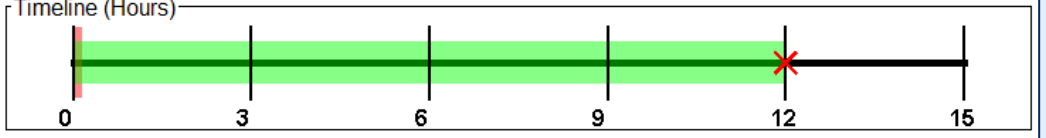
Extravasation Results

File Playback Speed

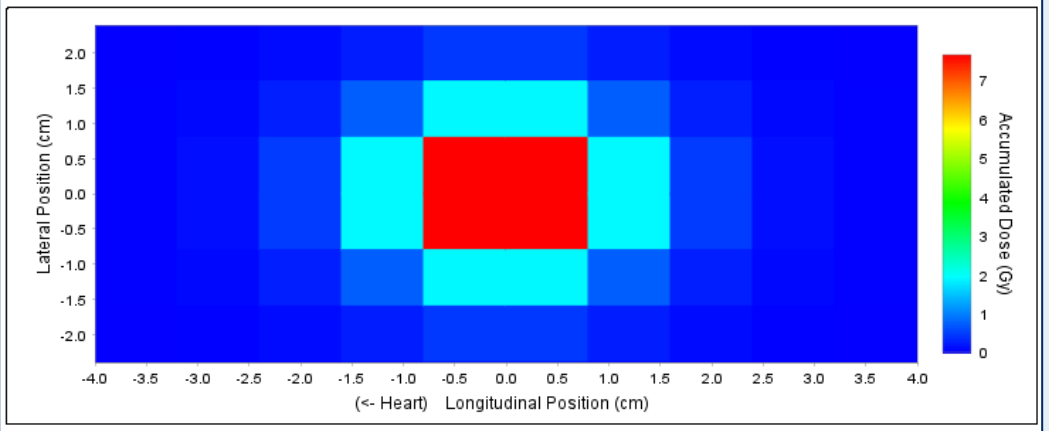
V+ Extravasation Dosimetry v1.0

RESULTS

Timeline (Hours)



Accumulated Dose [Gy] Activity Concentration [MBq/cm³] Absorbed Dose Rate [Gy/sec]



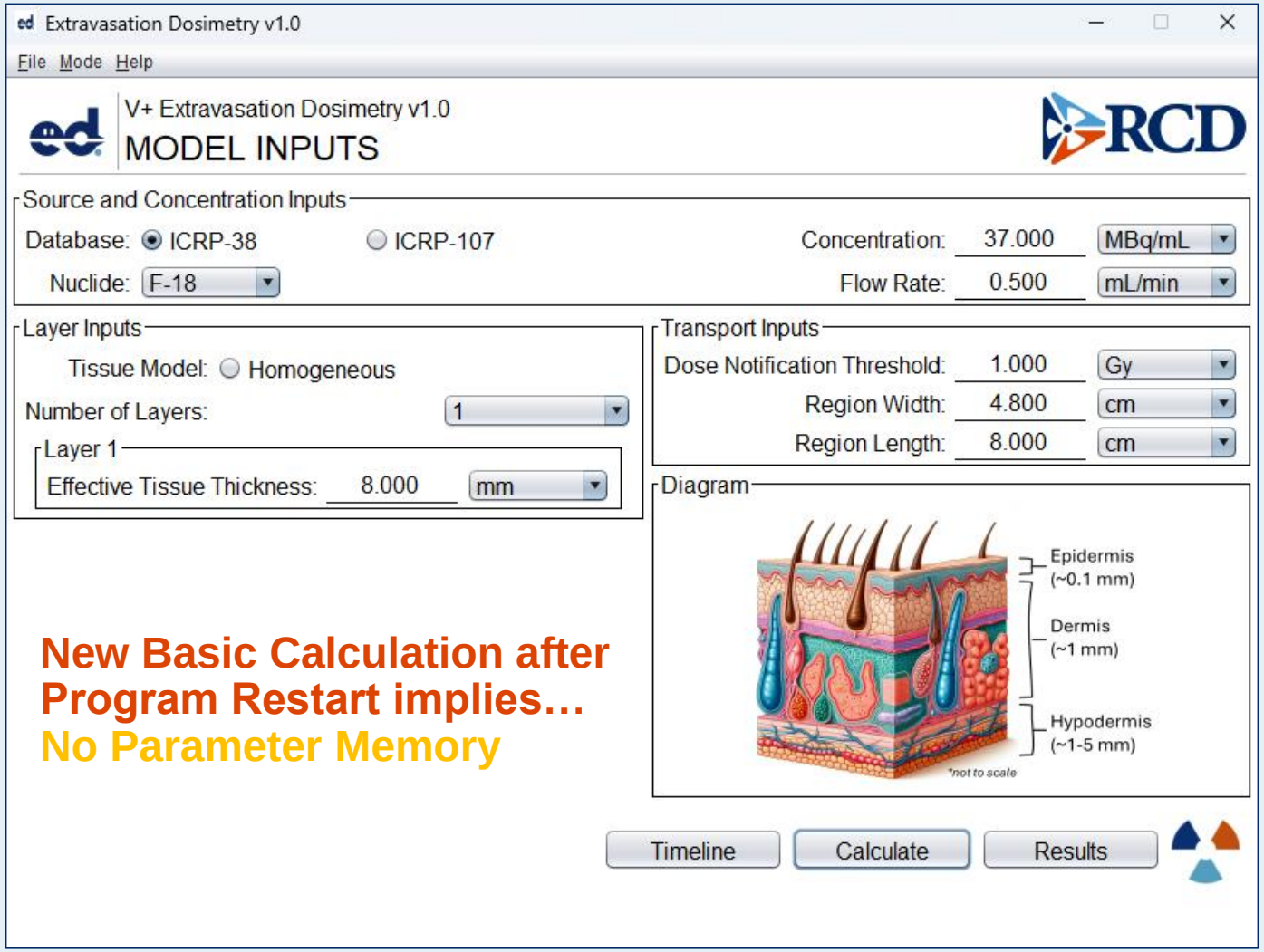
Time Controls

Previous | Play | Next | Reset

Time (min): 719.78

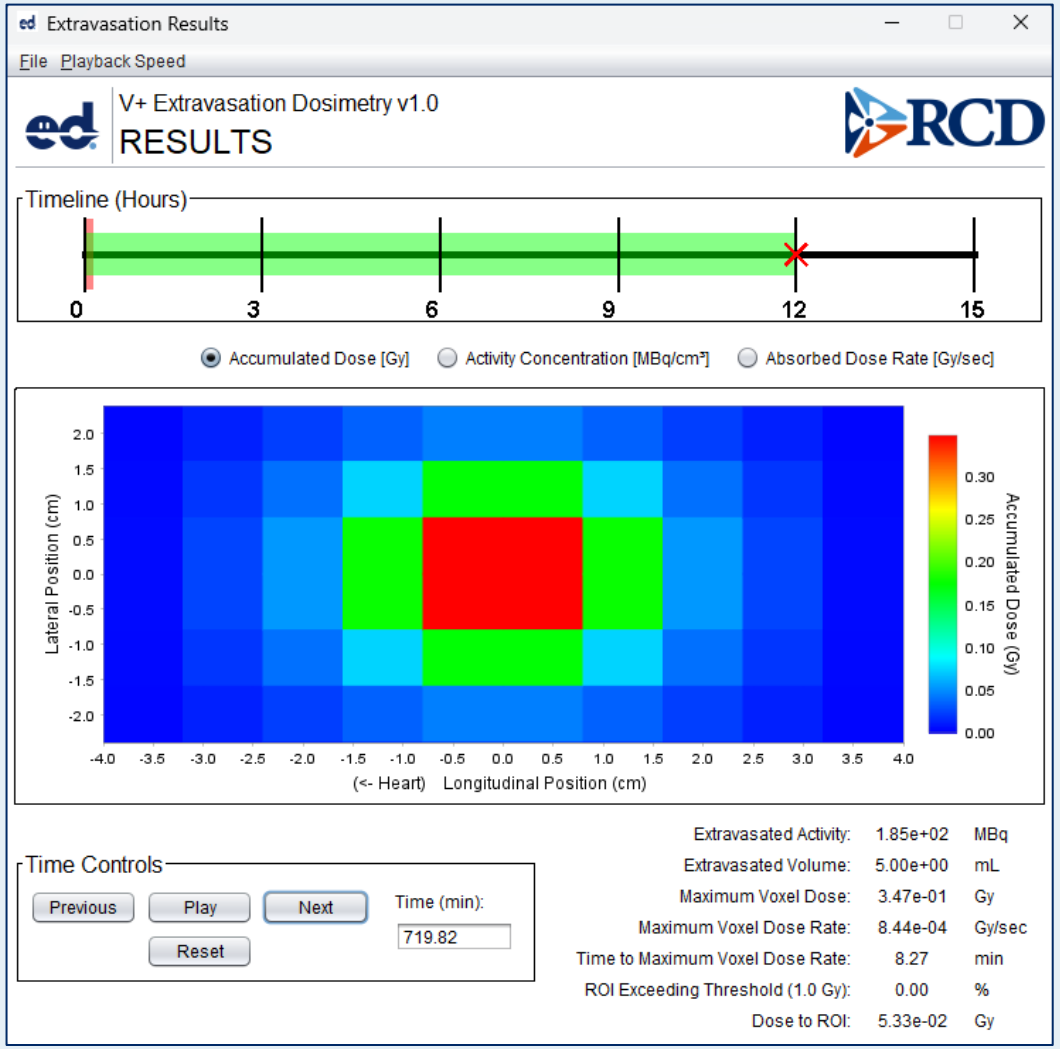
Extravasated Activity:	1.85e+02	MBq
Extravasated Volume:	5.00e+00	mL
Maximum Voxel Dose:	7.64e+00	Gy
Maximum Voxel Dose Rate:	1.06e-03	Gy/sec
Time to Maximum Voxel Dose Rate:	10.00	min
ROI Exceeding Threshold (1.0 Gy):	15.00	%
Dose to ROI:	7.09e-01	Gy

Parameter Memory Demonstrated (cont'd)



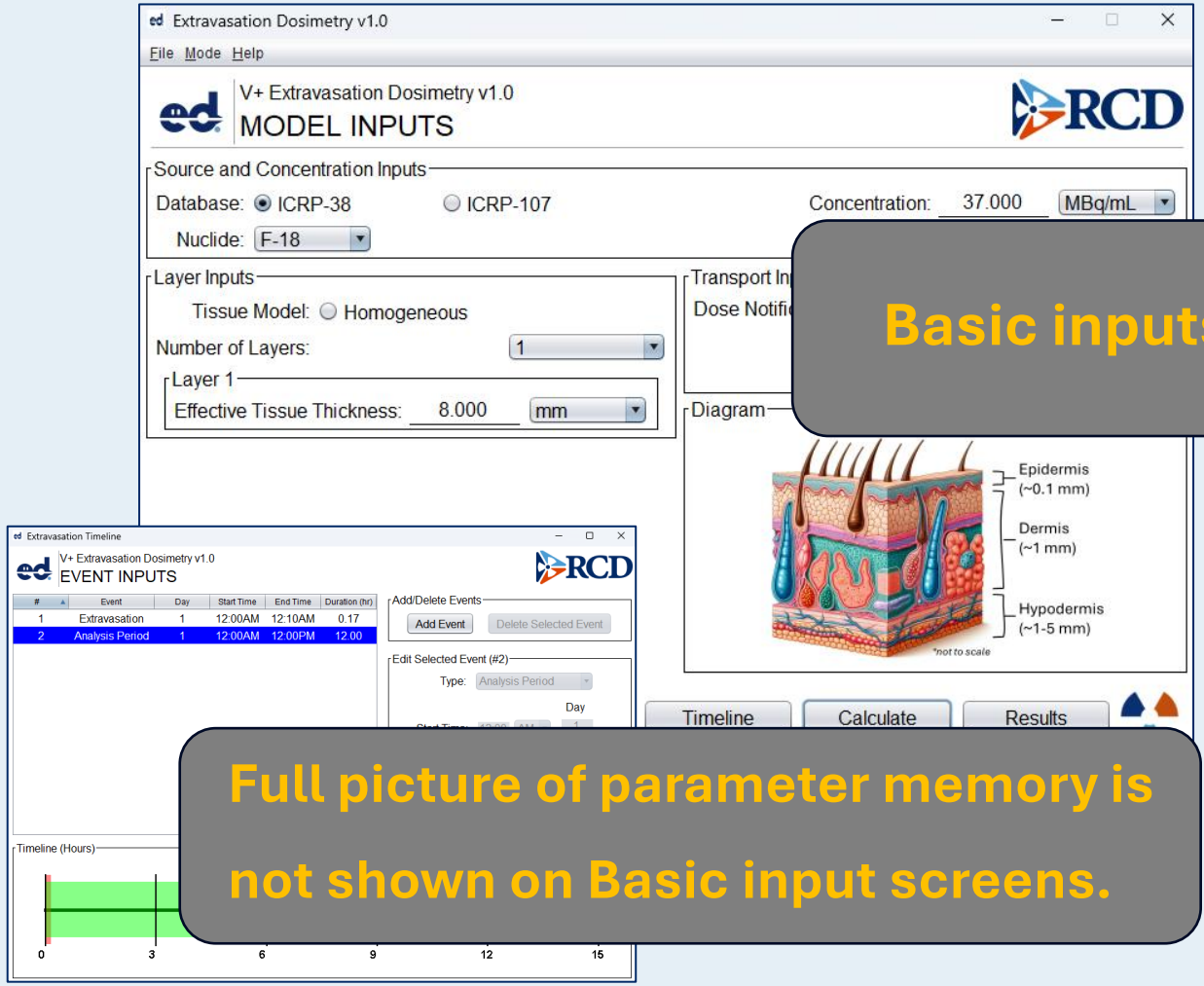
New Basic Calculation after Program Restart implies…

No Parameter Memory

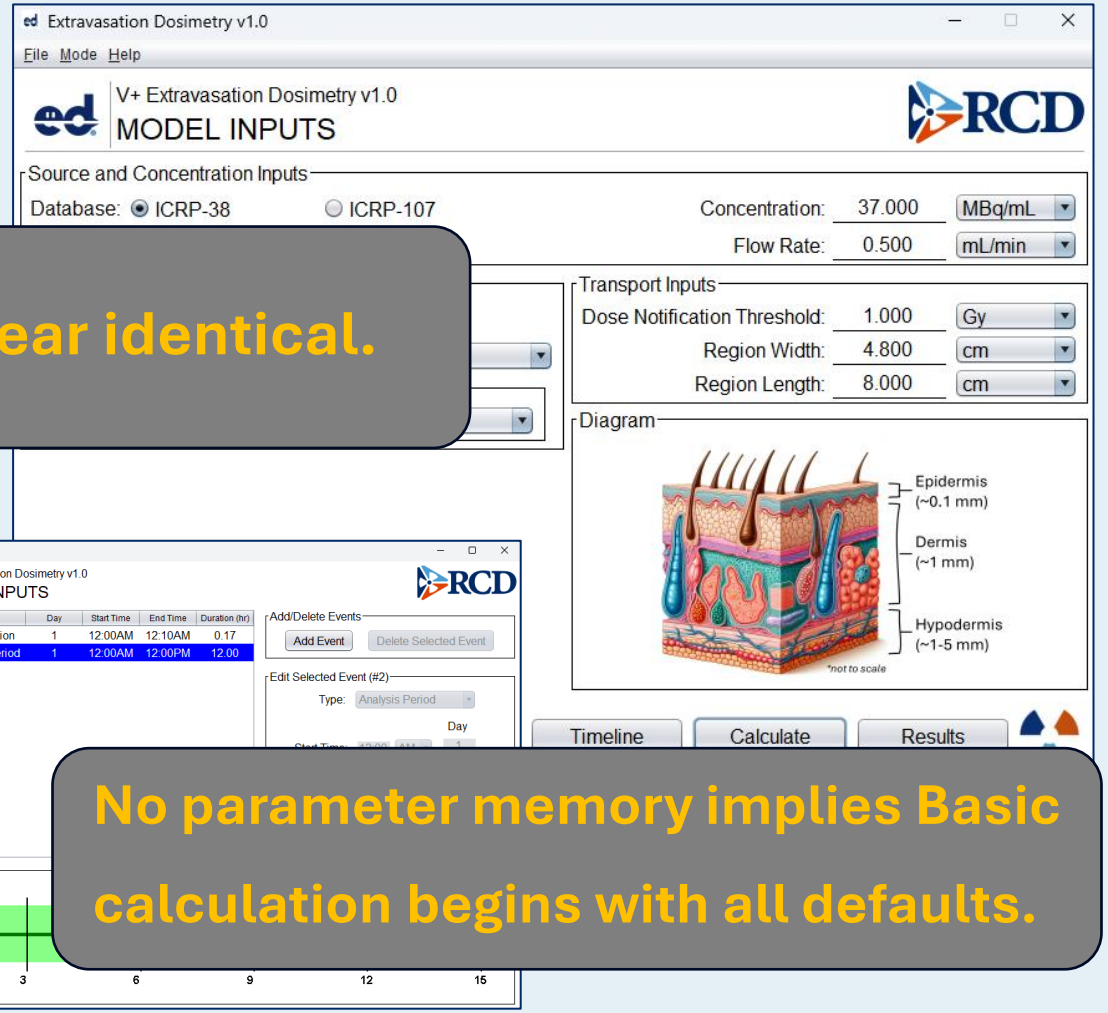


Parameter Memory Demonstrated (cont'd)

Basic Calculation after Advanced Calculation



New Basic Calculation after Program Restart



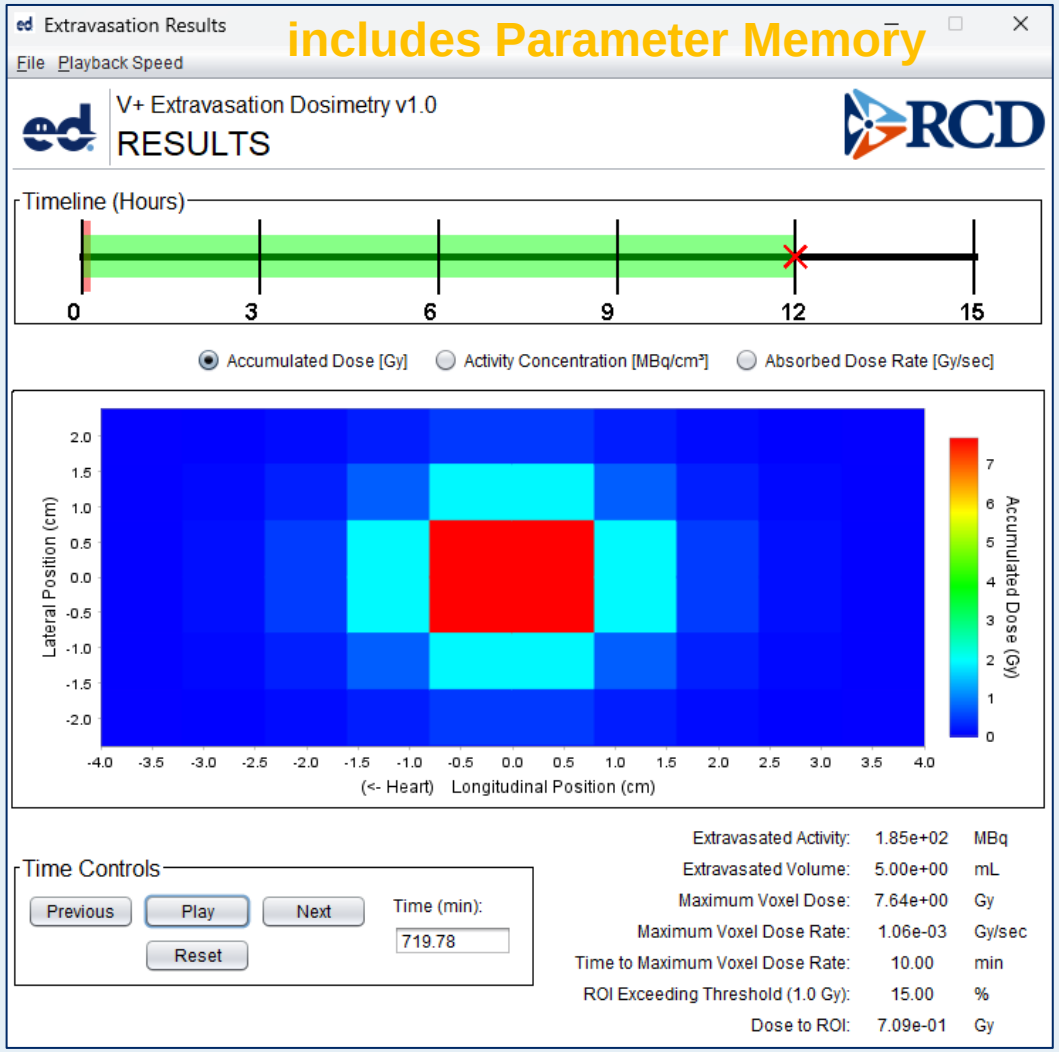
Basic inputs appear identical.

Full picture of parameter memory is not shown on Basic input screens.

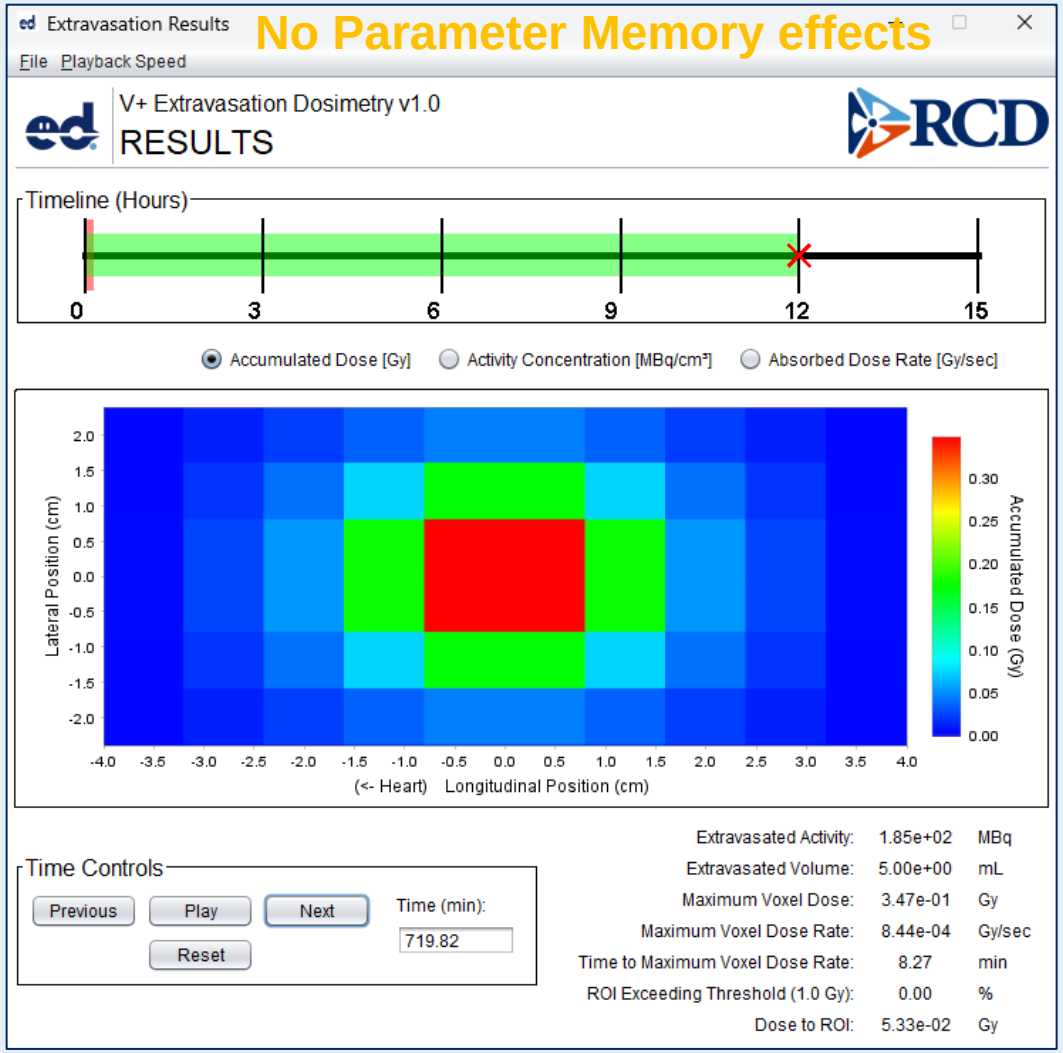
No parameter memory implies Basic calculation begins with all defaults.

Parameter Memory Can Influence Basic Calculation Results

Basic Calculation after Advanced Calculation



New Basic Calculation after Program Restart



V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/

ExtravDose Report Shows Parameter Values in Memory

Basic Calculation after Advanced Calculation

includes Parameter Memory

```
**********************************************************************************
User Inputs
**********************************************************************************
----------------------------------------------------------------------------------
Source and Concentration Information
----------------------------------------------------------------------------------
                                Database:       ICRP38
                                 Nuclide:         F-18
          Administration Concentration:         37.0      MBq/mL
              Administration Flow Rate:          0.5      mL/min
             Total Extravasated Volume:          5.0         mL
           Total Extravasated Activity:        185.0         MBq

----------------------------------------------------------------------------------
Layer Inputs
----------------------------------------------------------------------------------
                            Tissue Model:   Homogenous
                          Number of Layers:          1

                       Break Down by Layer

          Effective Tissue Thickness 1:          8.0         mm
              Lateral Transmissivity 1:         0.01      cm²/h

----------------------------------------------------------------------------------
Transport Inputs
----------------------------------------------------------------------------------
   Radiation Dose Notification Threshold:          1.0         Gy
                          Region Width:          4.8         cm
                         Region Length:          8.0         cm


                  Advanced Default Inputs
                  Vertical Transmissivity:         0.01      cm²/h
                        Fluid Diffusivity:         0.01      cm²/h
                  Cubic Voxel Side Length:          8.0         mm
```

New Basic Calculation after Program Restart

No Parameter Memory effects

```
**********************************************************************************
User Inputs
**********************************************************************************
----------------------------------------------------------------------------------
Source and Concentration Information
----------------------------------------------------------------------------------
                                Database:       ICRP38
                                 Nuclide:         F-18
          Administration Concentration:         37.0      MBq/mL
              Administration Flow Rate:          0.5      mL/min
             Total Extravasated Volume:          5.0         mL
           Total Extravasated Activity:        185.0         MBq

----------------------------------------------------------------------------------
Layer Inputs
----------------------------------------------------------------------------------
                            Tissue Model:   Homogenous
                          Number of Layers:          1

                       Break Down by Layer

          Effective Tissue Thickness 1:          8.0         mm
              Lateral Transmissivity 1:          3.0      cm²/h

----------------------------------------------------------------------------------
Transport Inputs
----------------------------------------------------------------------------------
   Radiation Dose Notification Threshold:          1.0         Gy
                          Region Width:          4.8         cm
                         Region Length:          8.0         cm


                  Advanced Default Inputs
                  Vertical Transmissivity:          1.0      cm²/h
                        Fluid Diffusivity:          0.1      cm²/h
                  Cubic Voxel Side Length:          8.0         mm
```

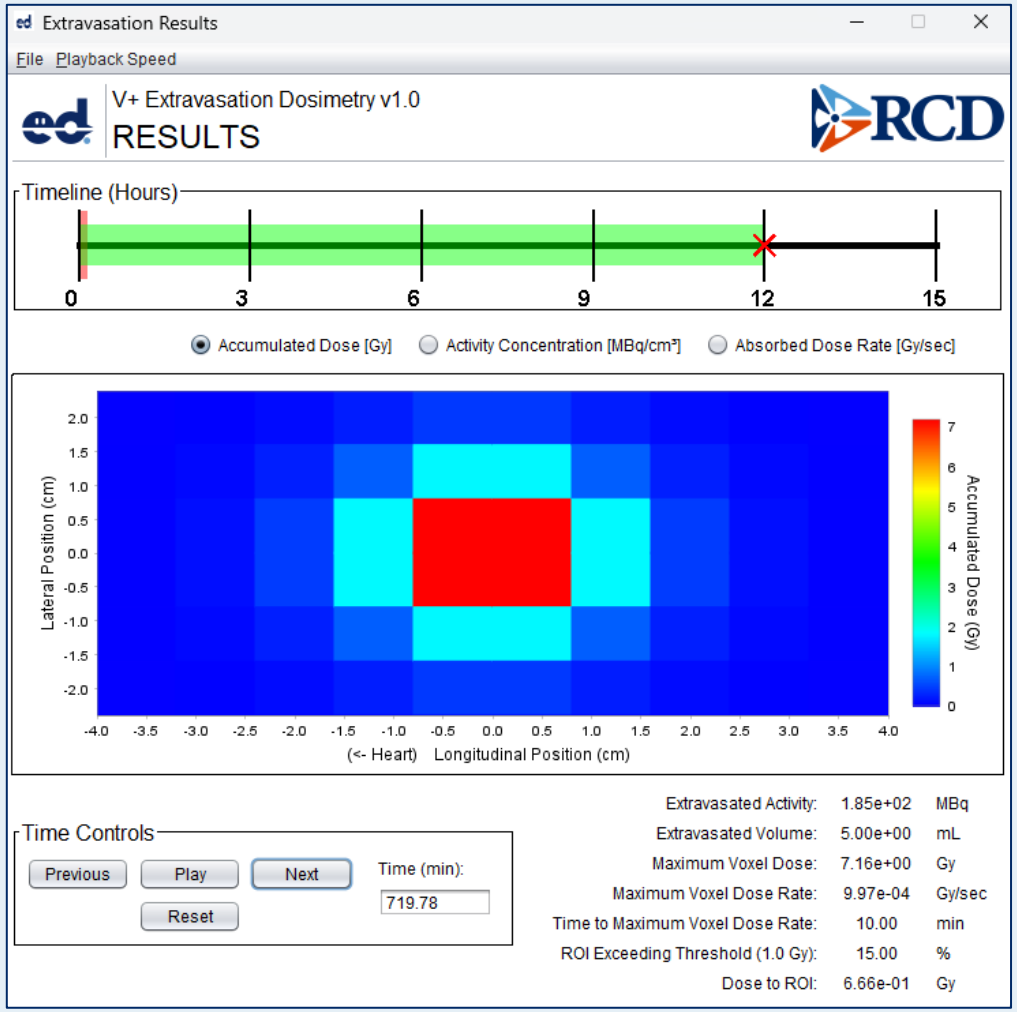
Example V: Trapped fluid with different radionuclides

- **Small values for transmissivity**
- **Small value for diffusivity**

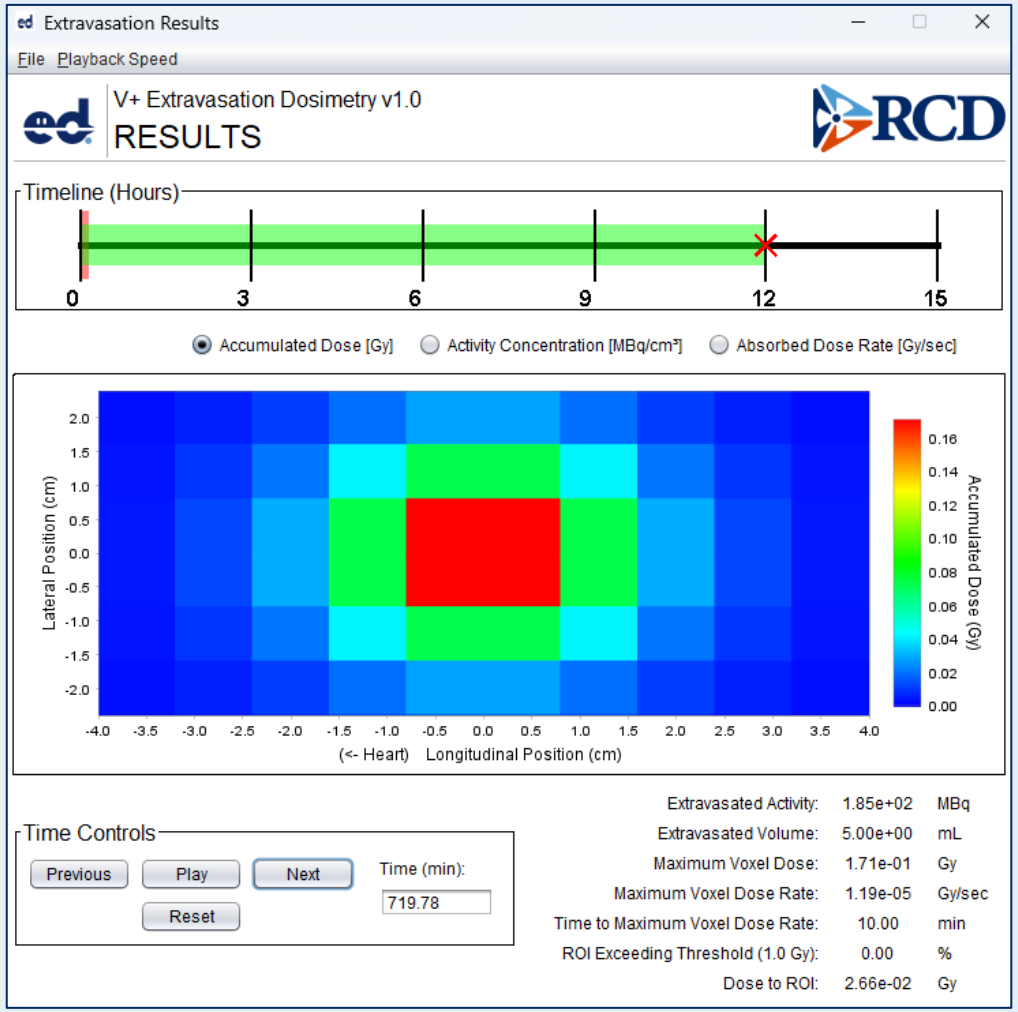
5-mCi Activity in Trapped Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.01 cm^2/h

^{18}F 0.67 Gy to ROI



^{99m}Tc 0.03 Gy to ROI

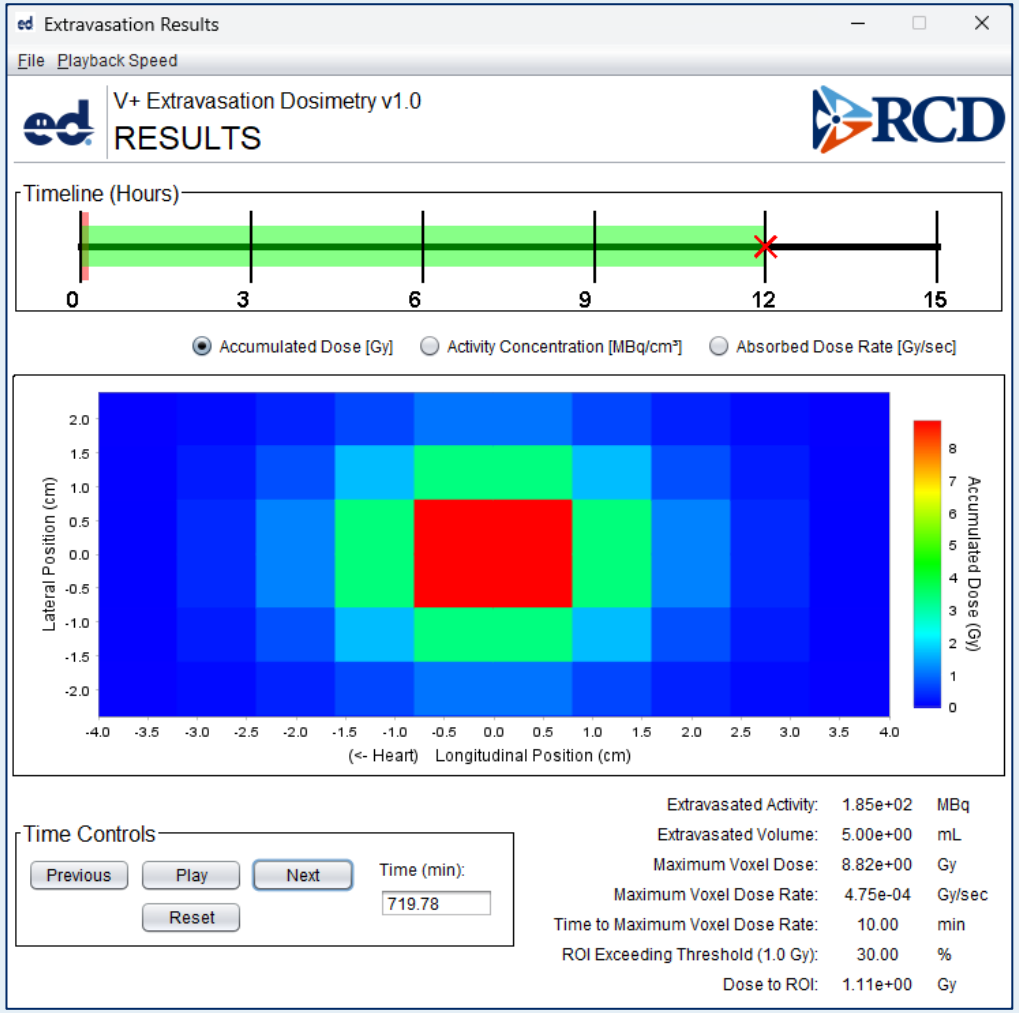


V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/

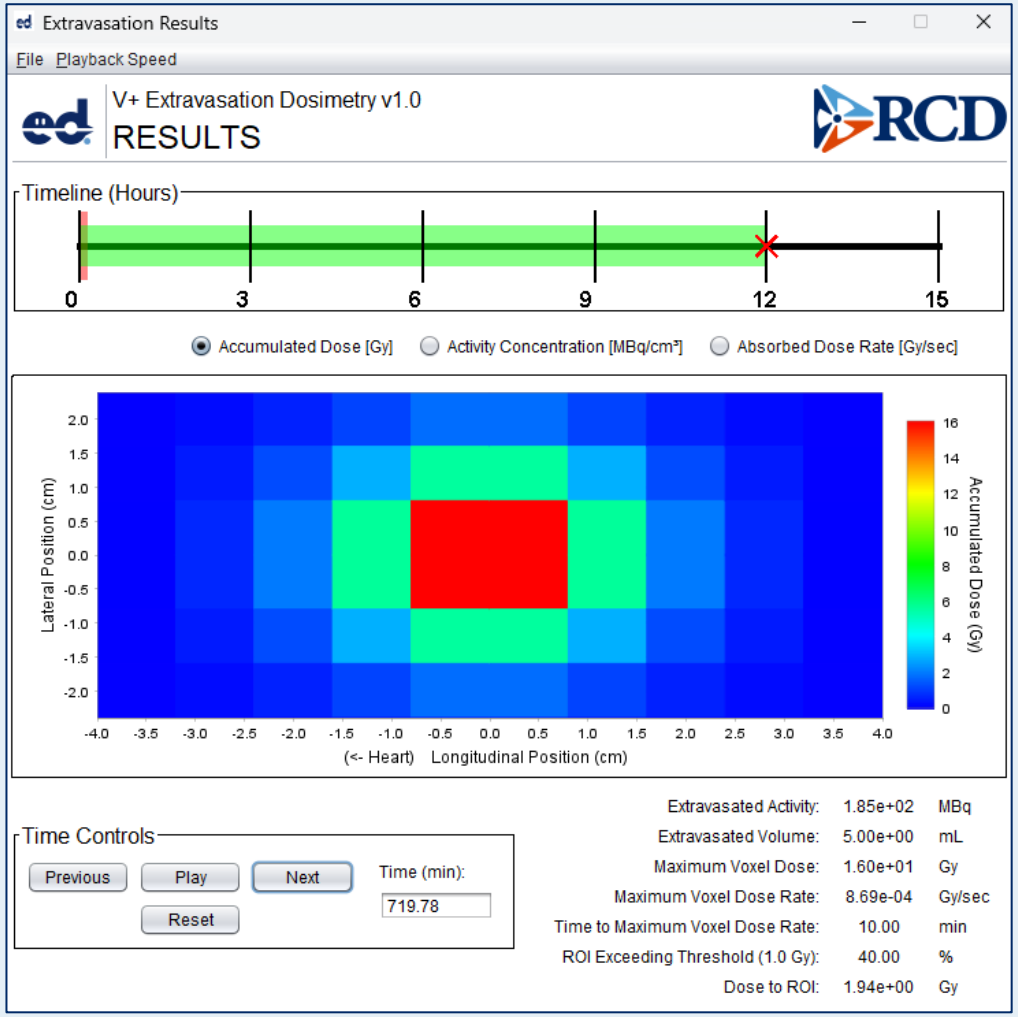
5-mCi Activity in Trapped Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.01 cm^2/h

^{90}Y 1.1 Gy to ROI



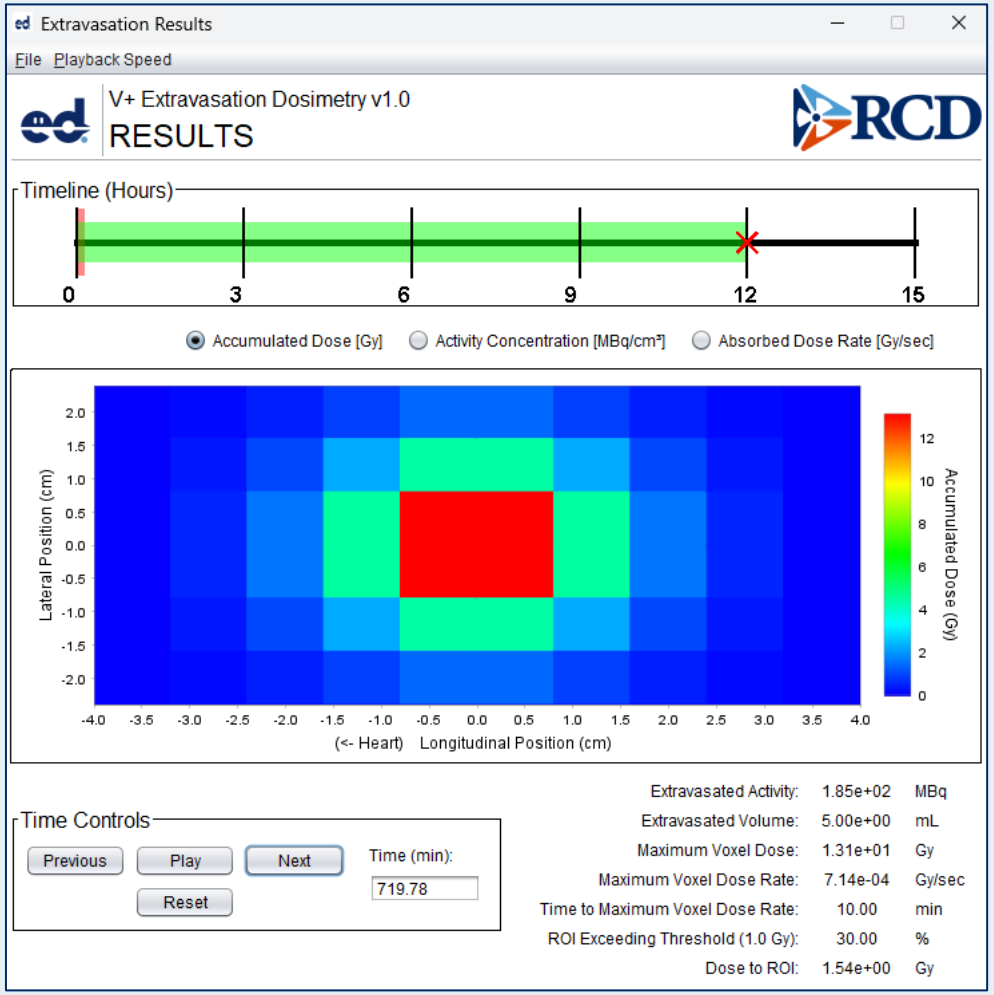
^{131}I 1.9 Gy to ROI



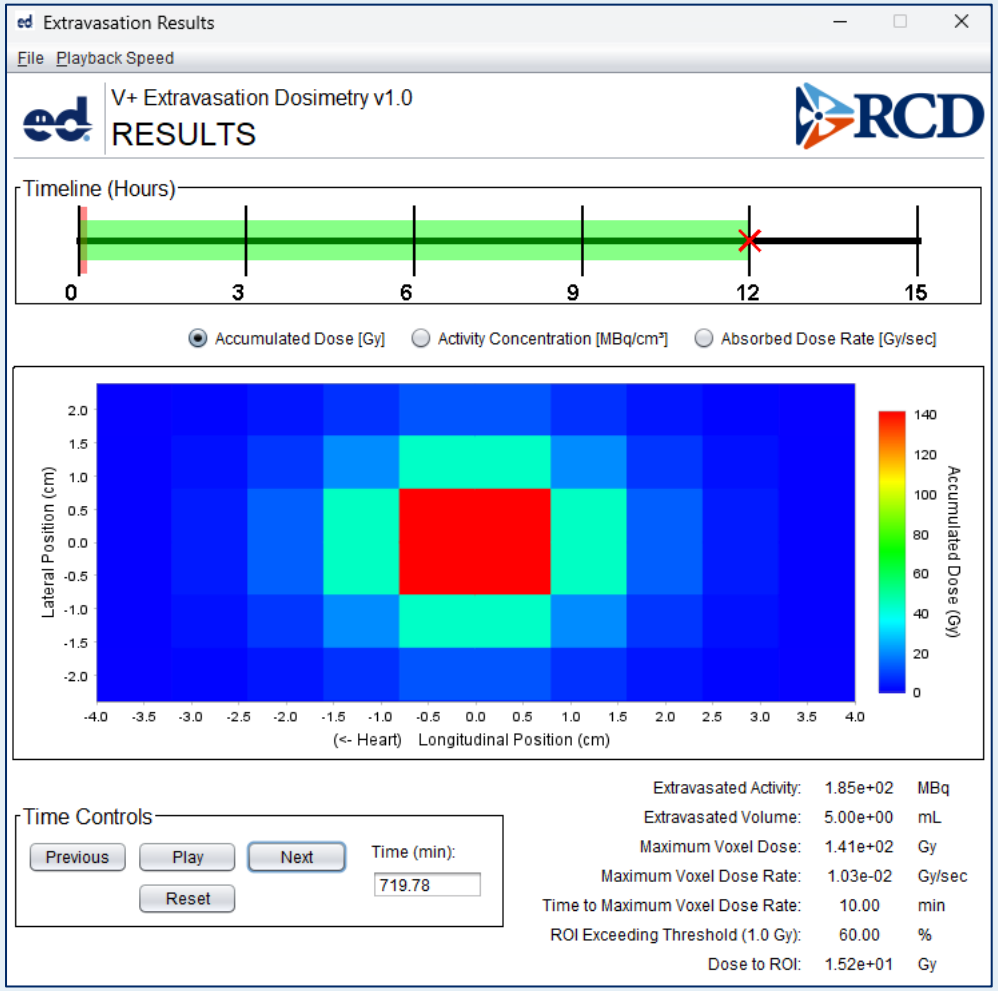
5-mCi Activity in Trapped Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.01 cm^2/h

^{177}Lu 1.5 Gy to ROI



^{211}At 15 Gy to ROI

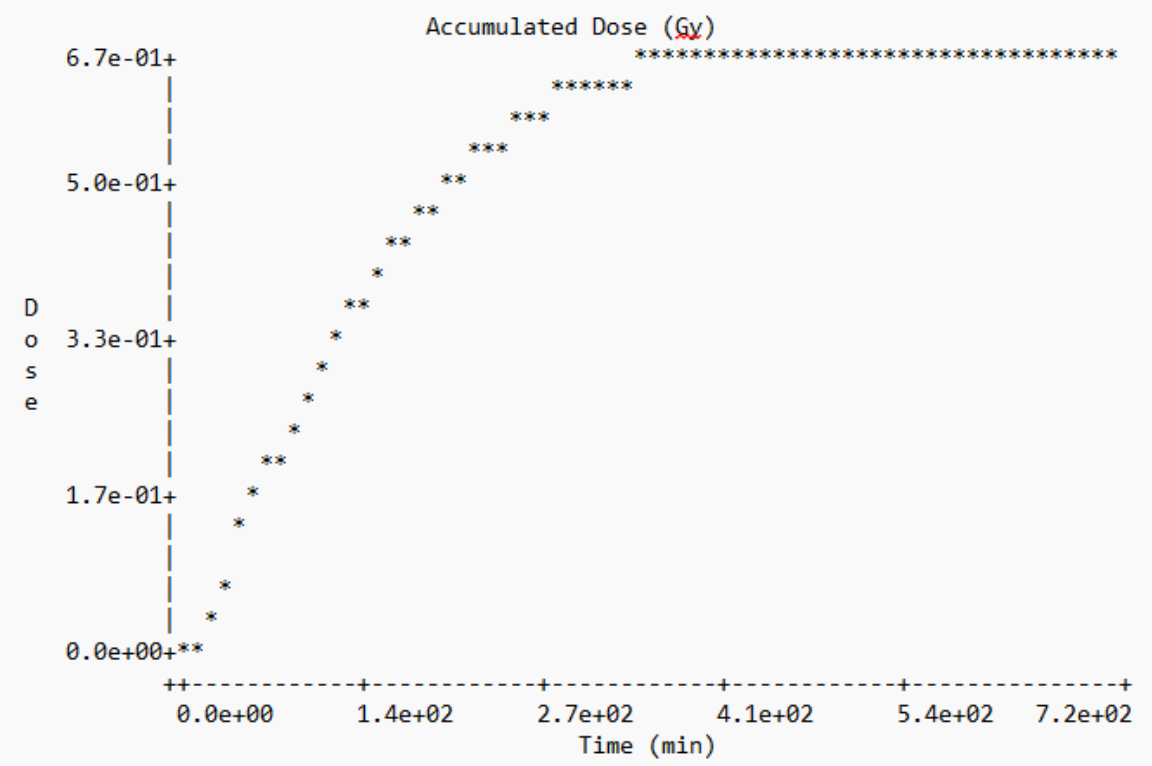


V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/

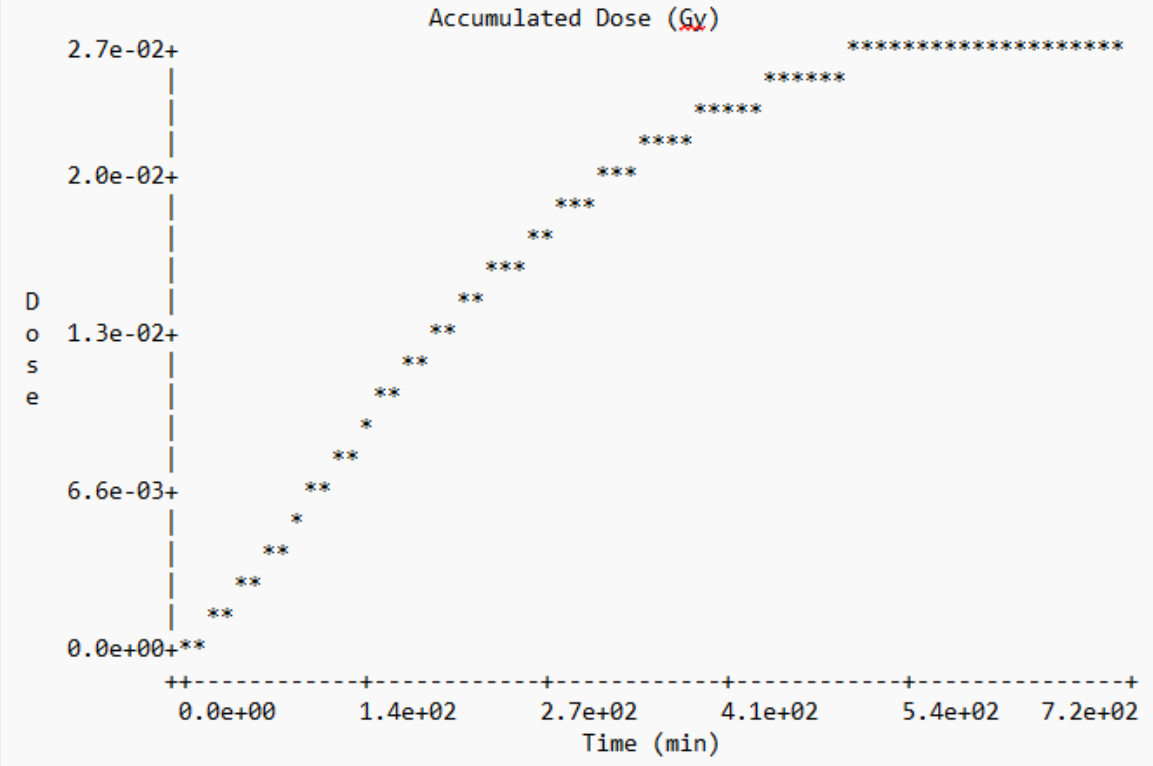
5-mCi Activity in Trapped Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.01 cm^2/h

^{18}F 0.67 Gy to ROI



^{99m}Tc 0.03 Gy to ROI

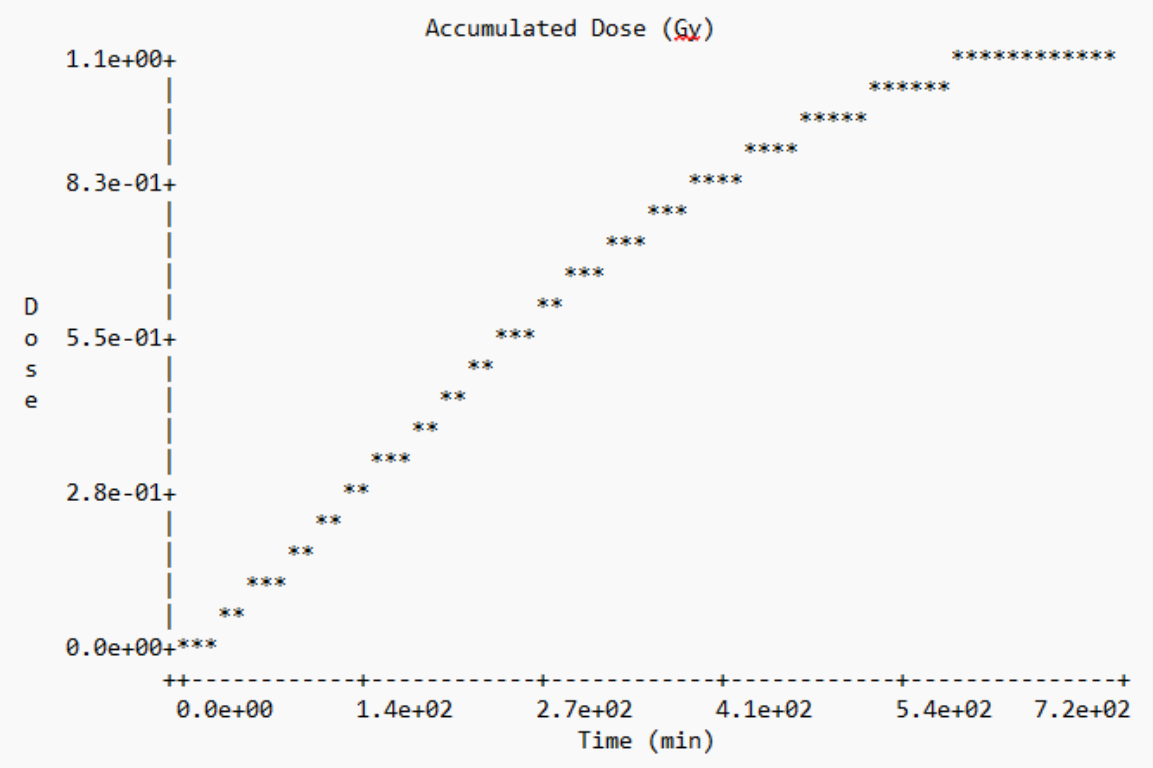


V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/

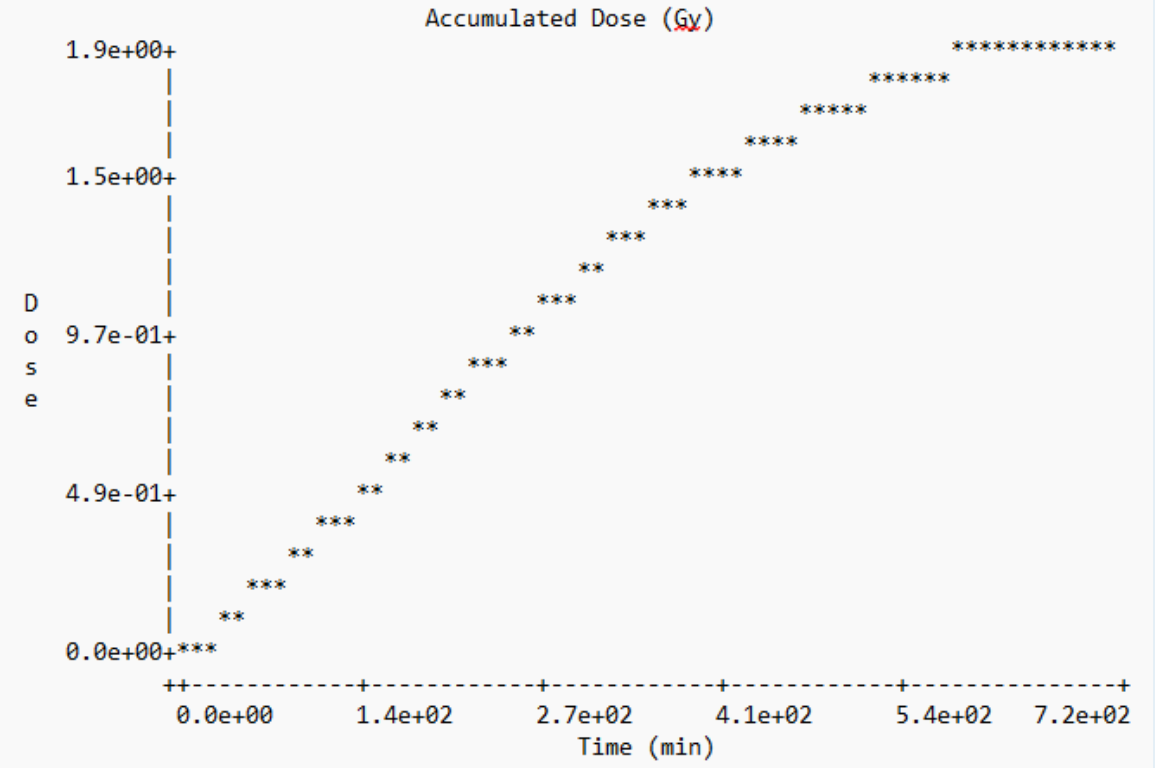
5-mCi Activity in Trapped Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.01 cm^2/h

^{90}Y 1.1 Gy to ROI



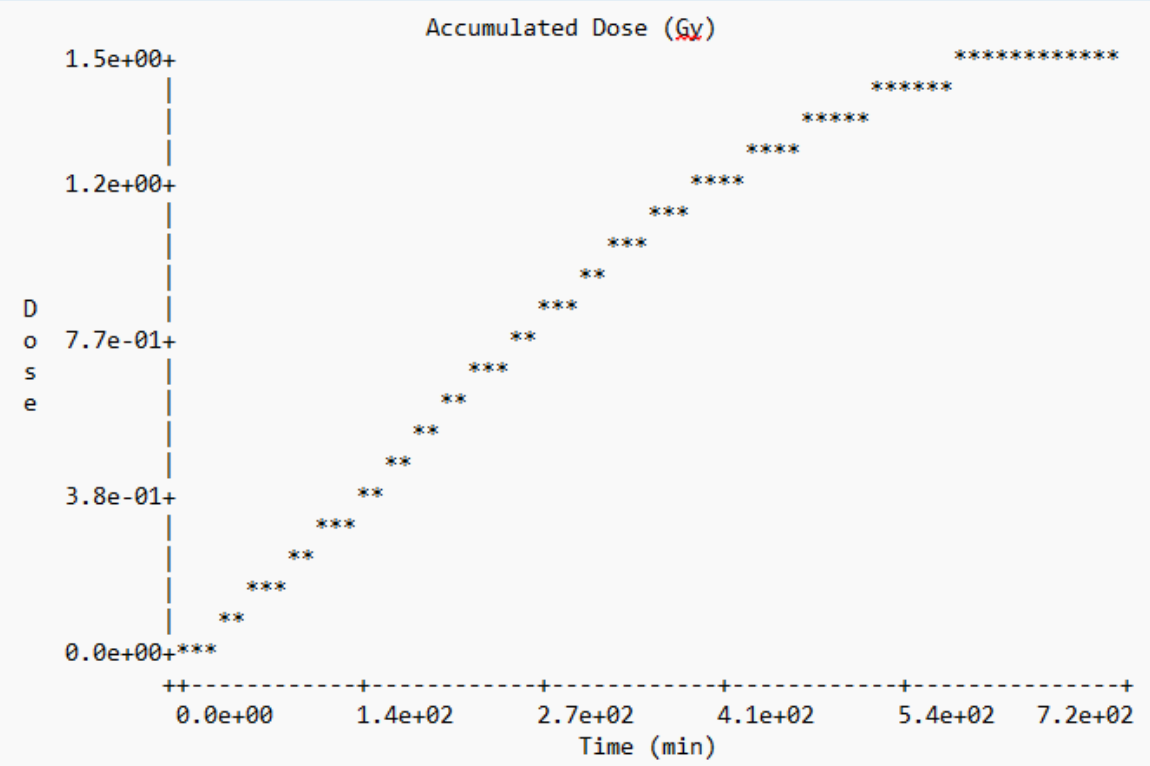
^{131}I 1.9 Gy to ROI



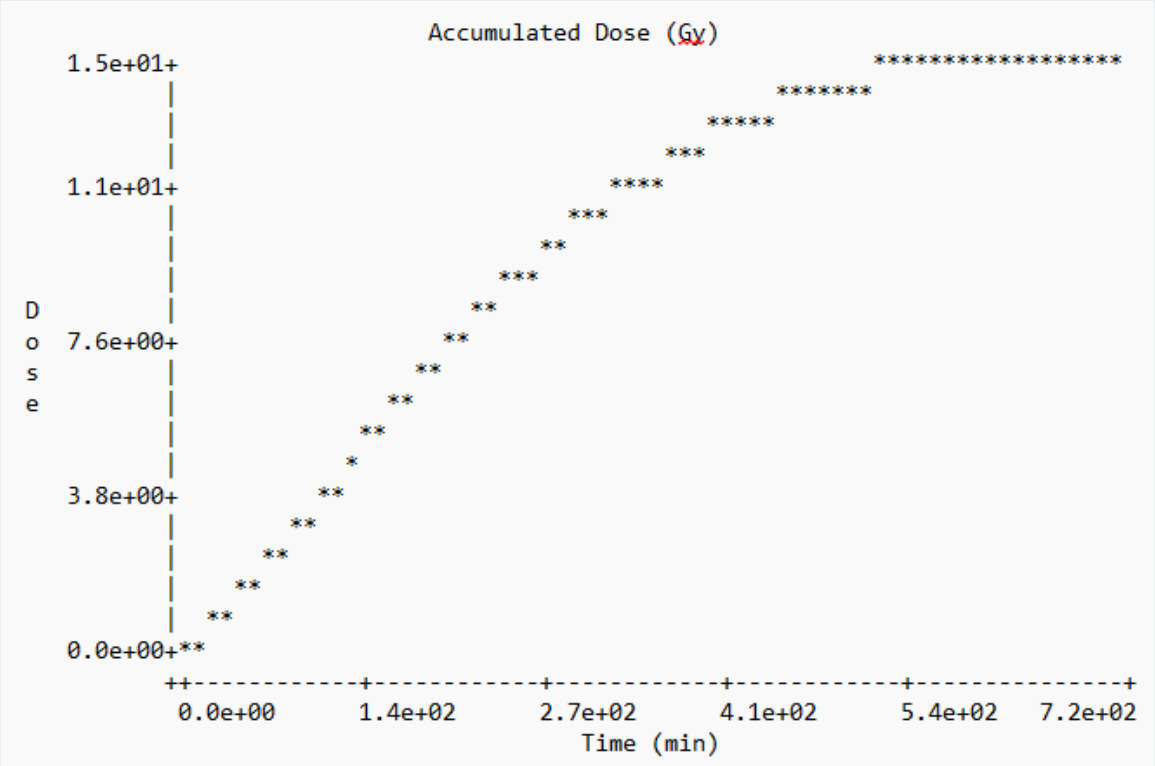
5-mCi Activity in Trapped Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.01 cm^2/h

^{177}Lu 1.5 Gy to ROI



^{211}At 15 Gy to ROI



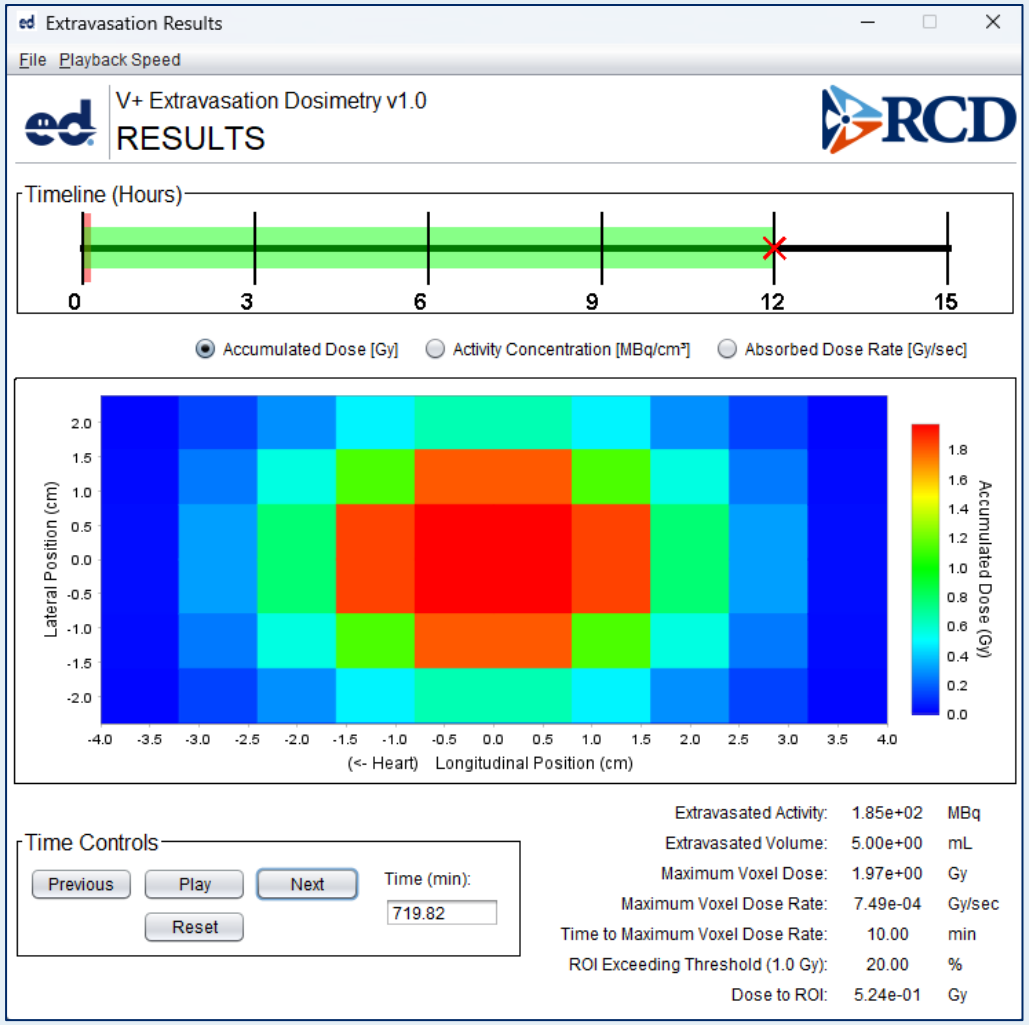
Example VI: Lateral fluid flow with different radionuclides

5-mCi Activity in Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.1 cm^2/h

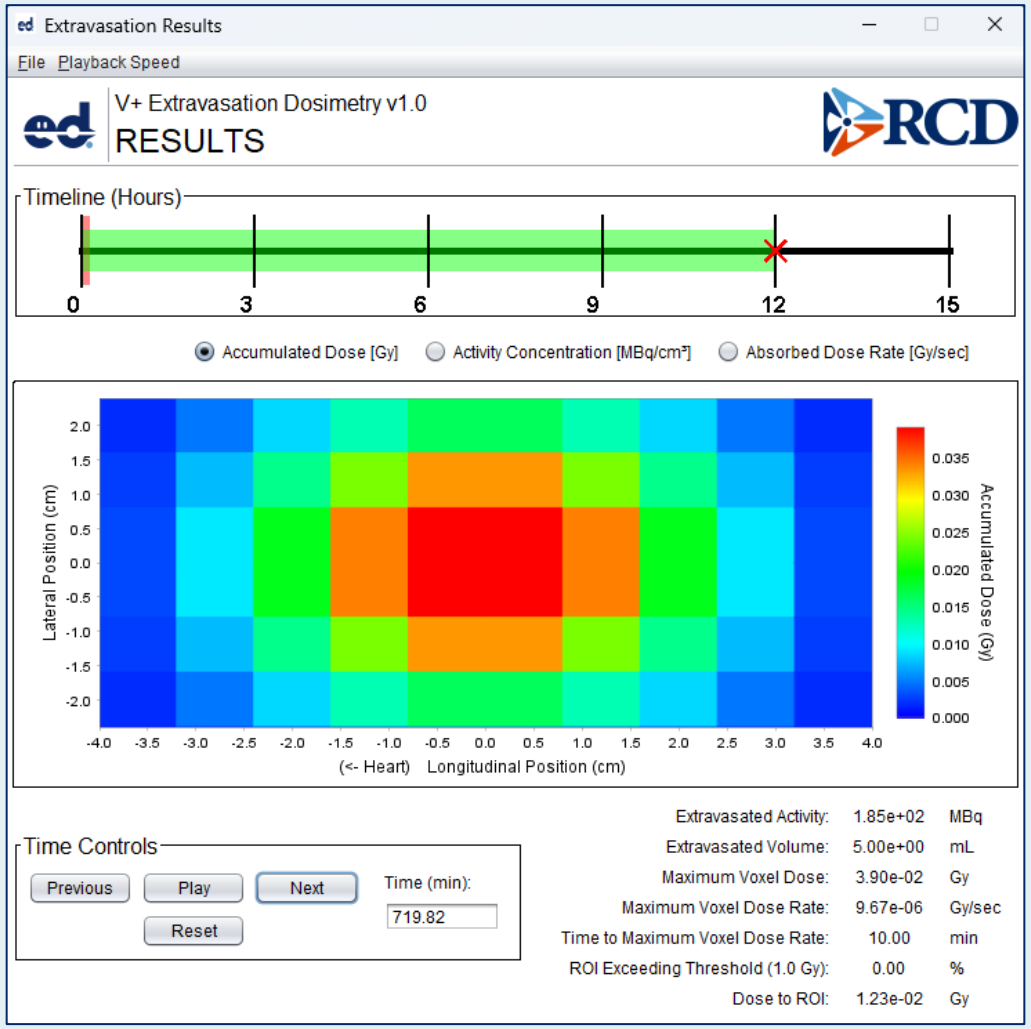
^{18}F 0.52 Gy to ROI

Physical half-life 1.8 h



^{99m}Tc 0.01 Gy to ROI

Physical half-life 6.0 h

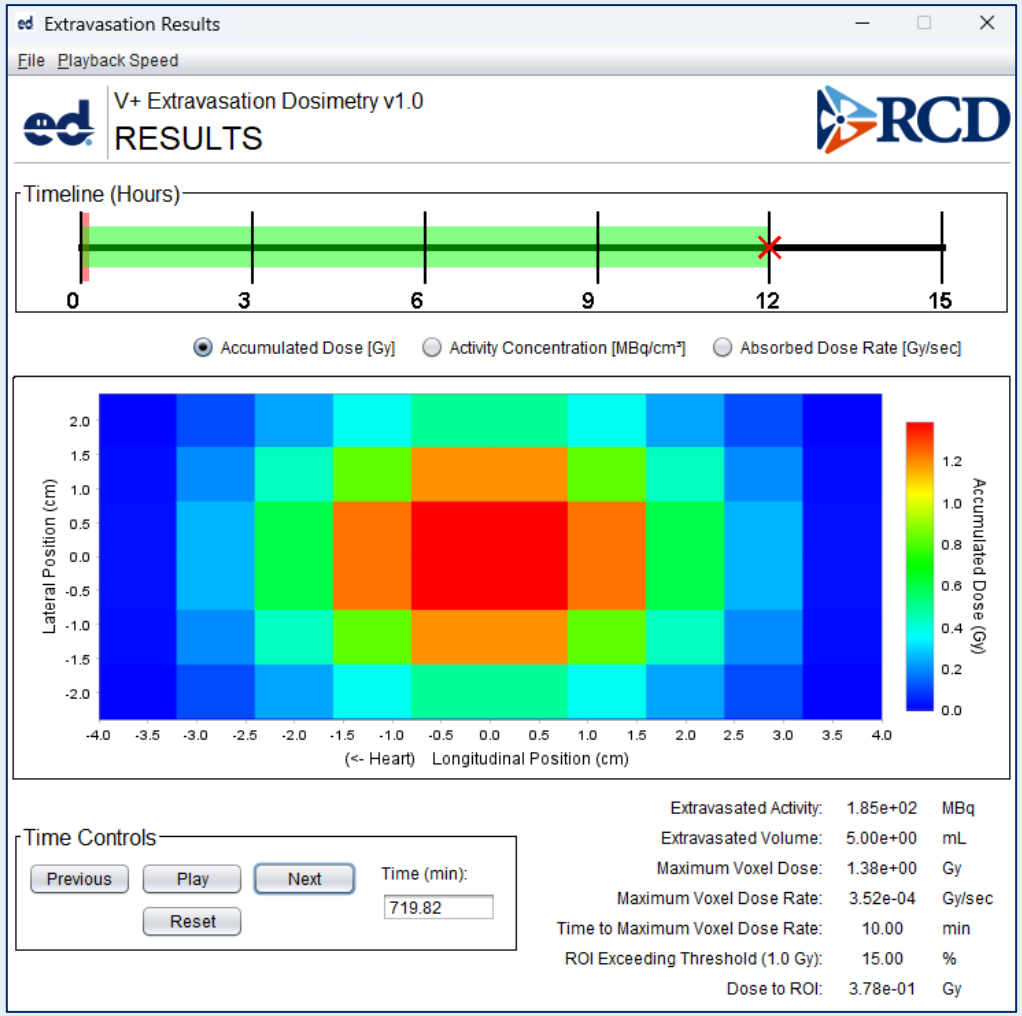


V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/

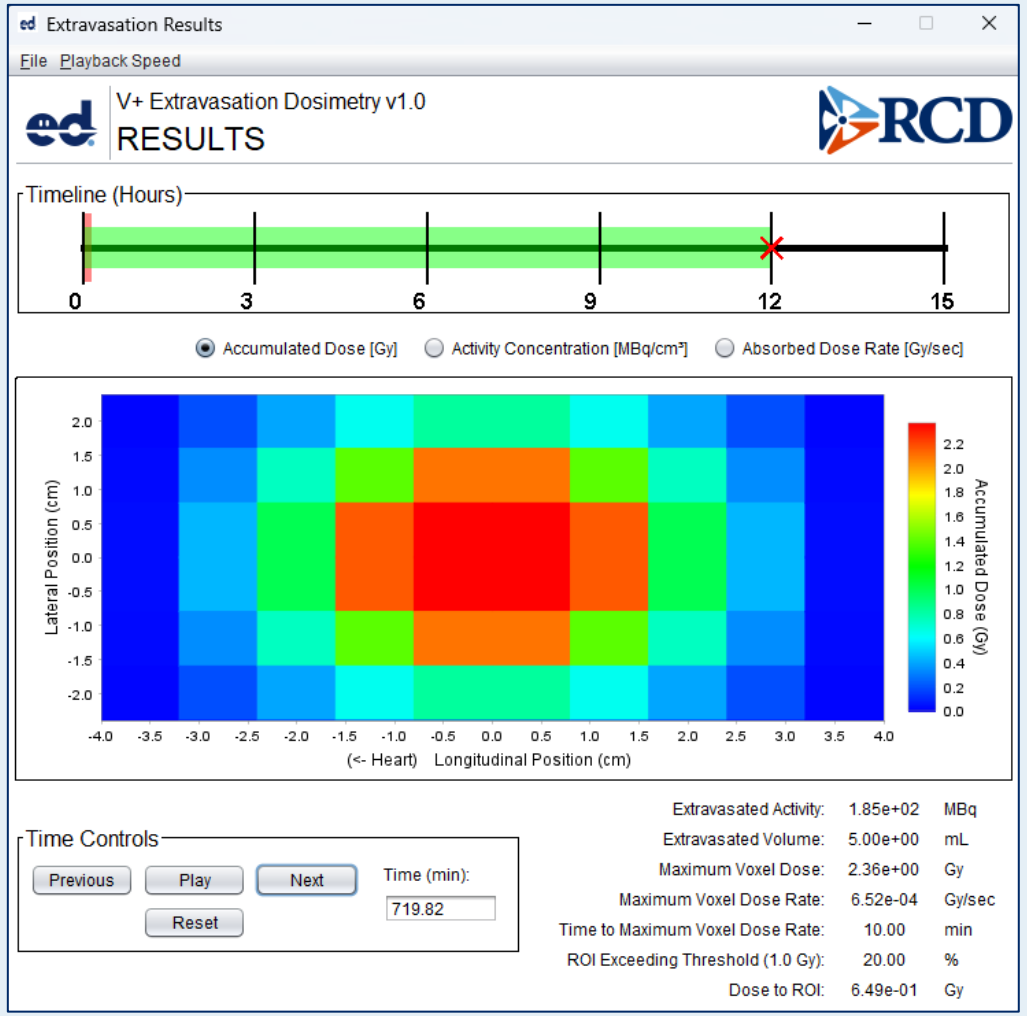
5-mCi Activity in Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.1 cm^2/h

^{90}Y 0.38 Gy to ROI — Physical half-life 64 h



^{131}I 0.65 Gy to ROI — Physical half-life 192 h



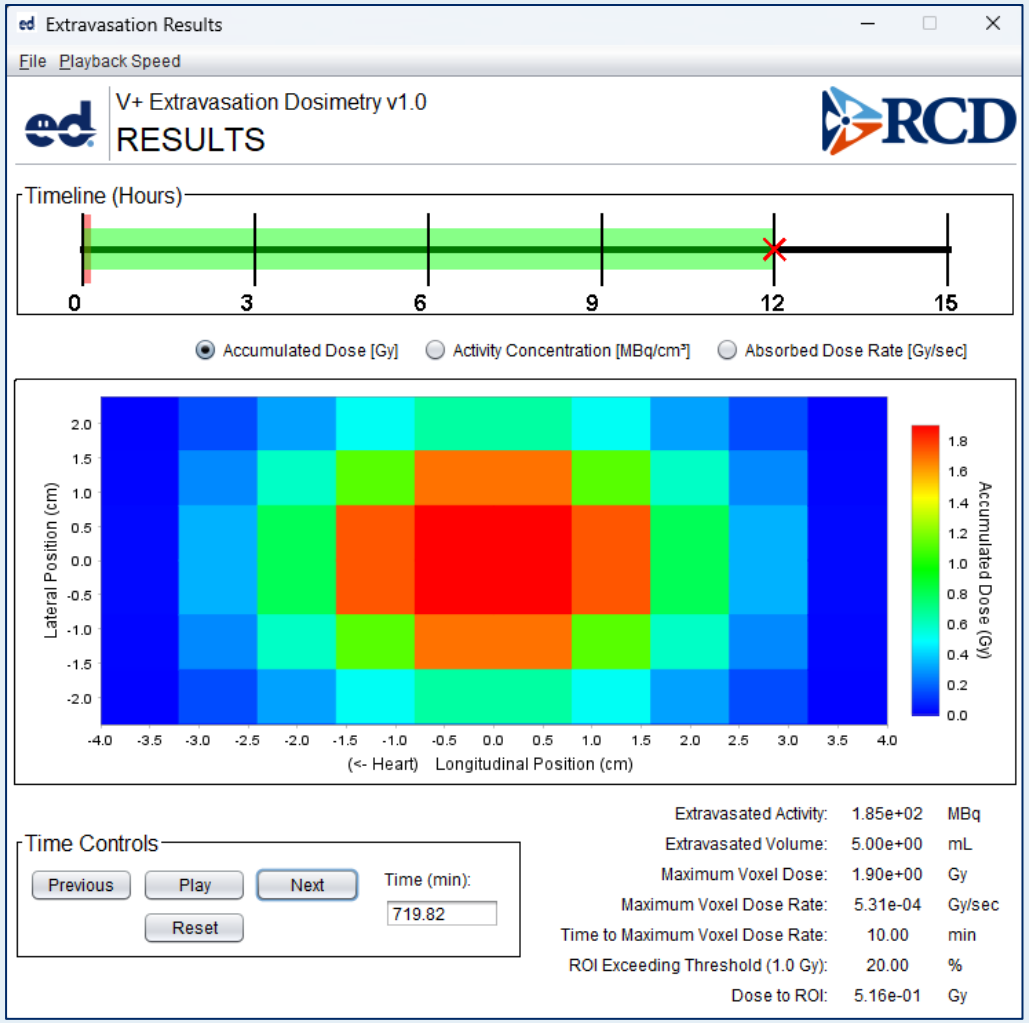
V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/

5-mCi Activity in Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.1 cm^2/h

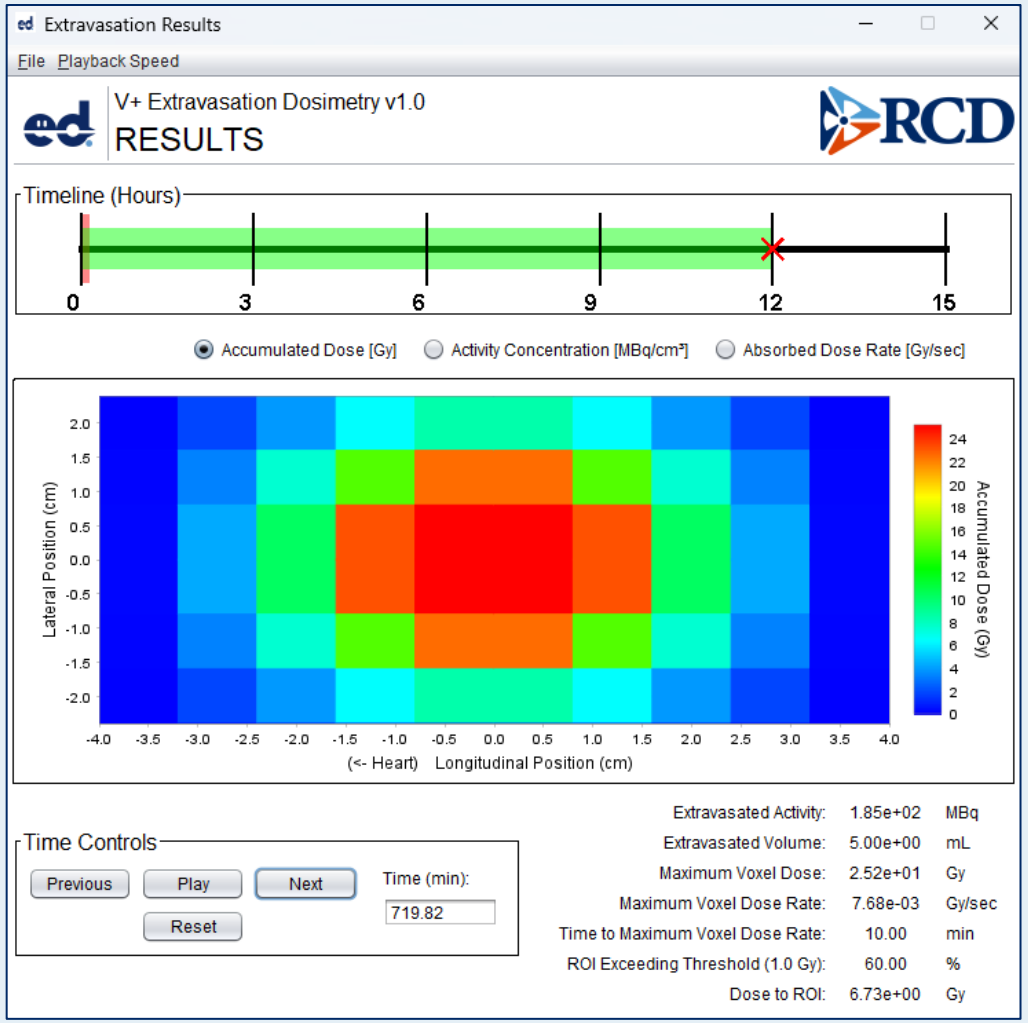
^{177}Lu 0.52 Gy to ROI

Physical half-life 160 h



^{211}At 6.7 Gy to ROI

Physical half-life 7.2 h

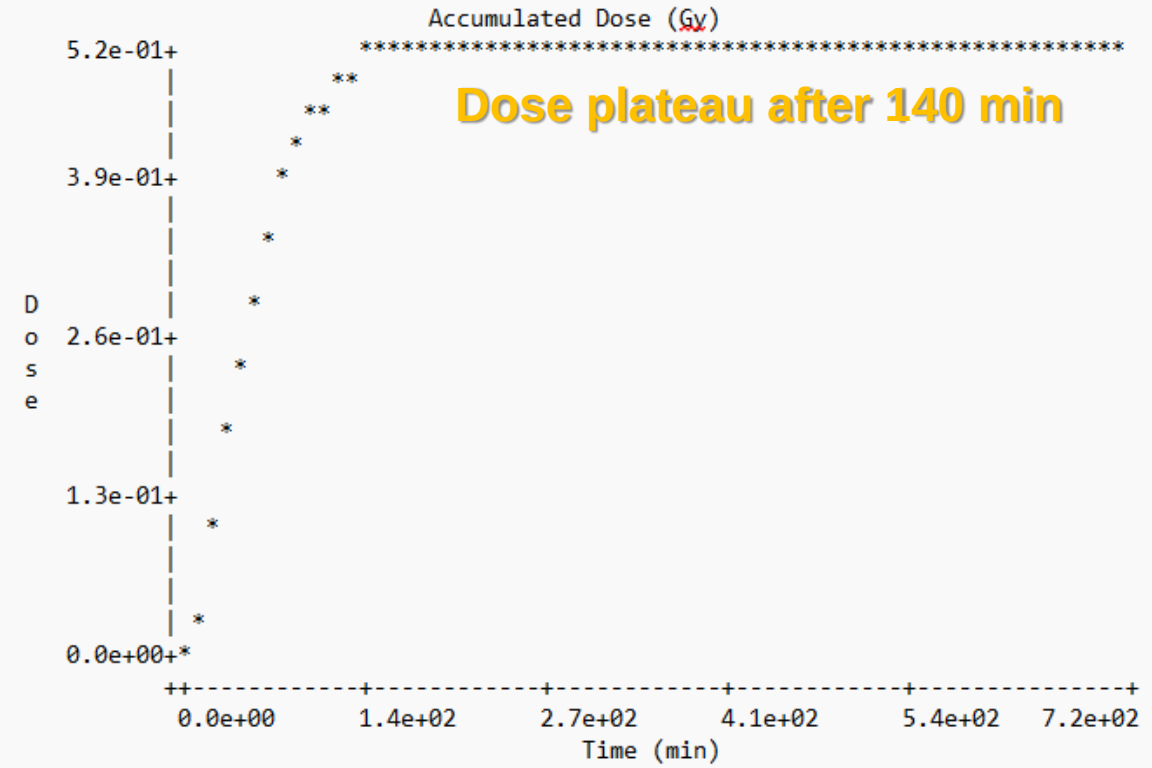


V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/

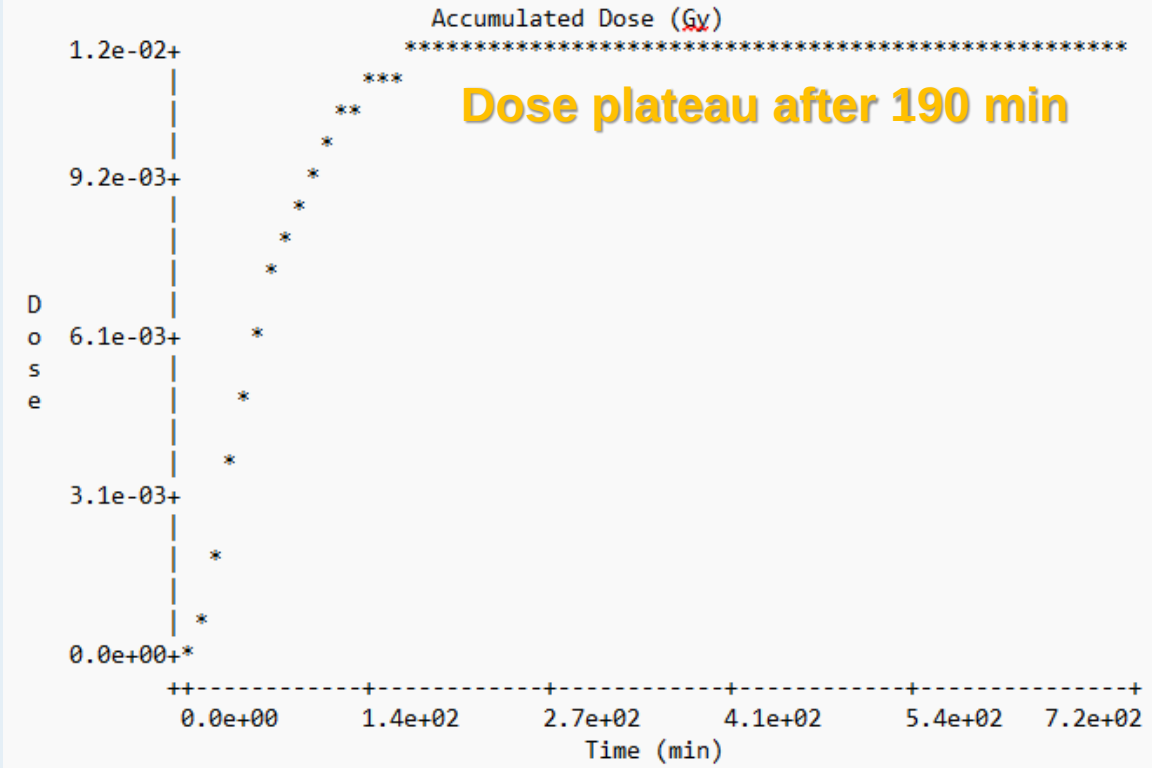
5-mCi Activity in Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.1 cm^2/h

^{18}F 0.52 Gy to ROI Physical half-life 1.8 h



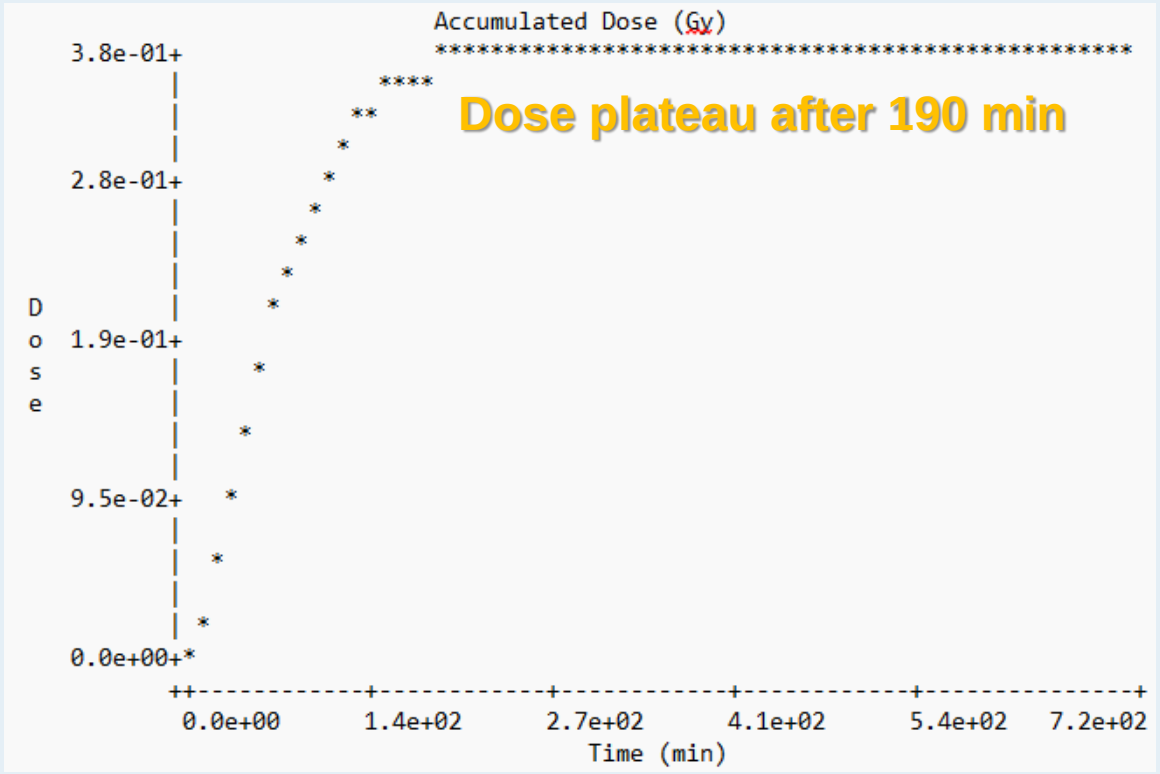
^{99m}Tc 0.01 Gy to ROI Physical half-life 6.0 h



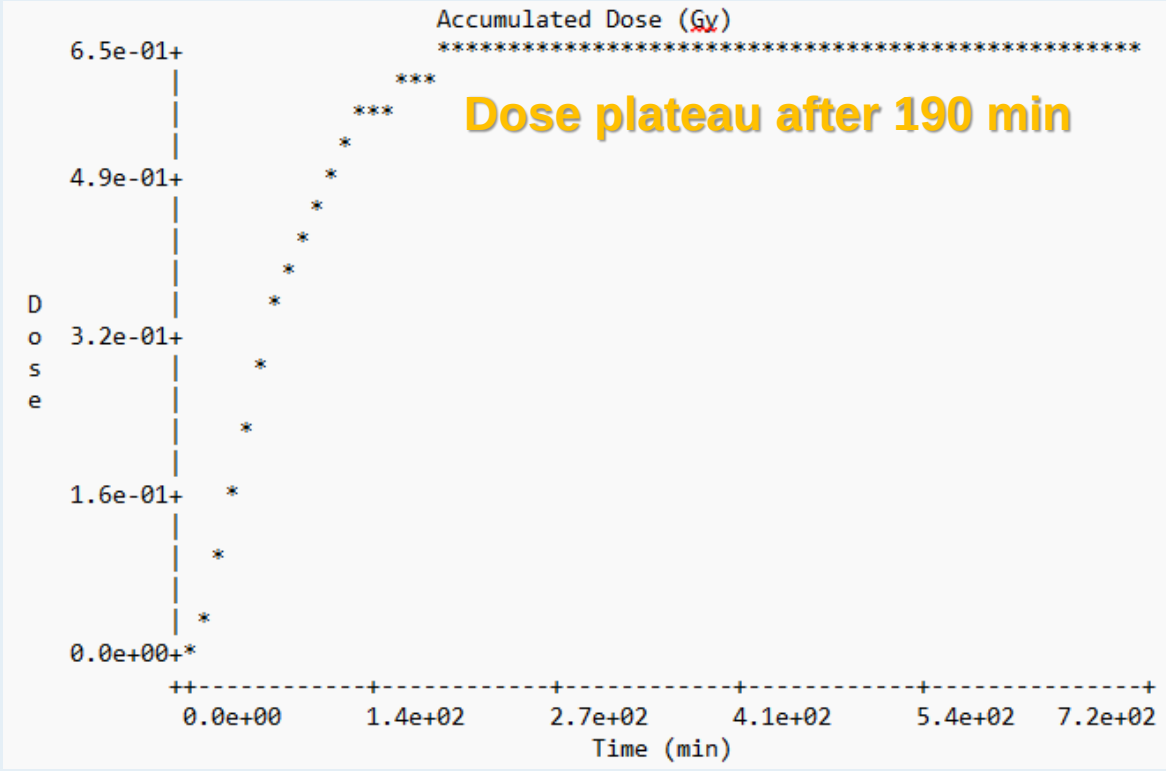
5-mCi Activity in Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.1 cm^2/h

^{90}Y 0.38 Gy to ROI Physical half-life 64 h



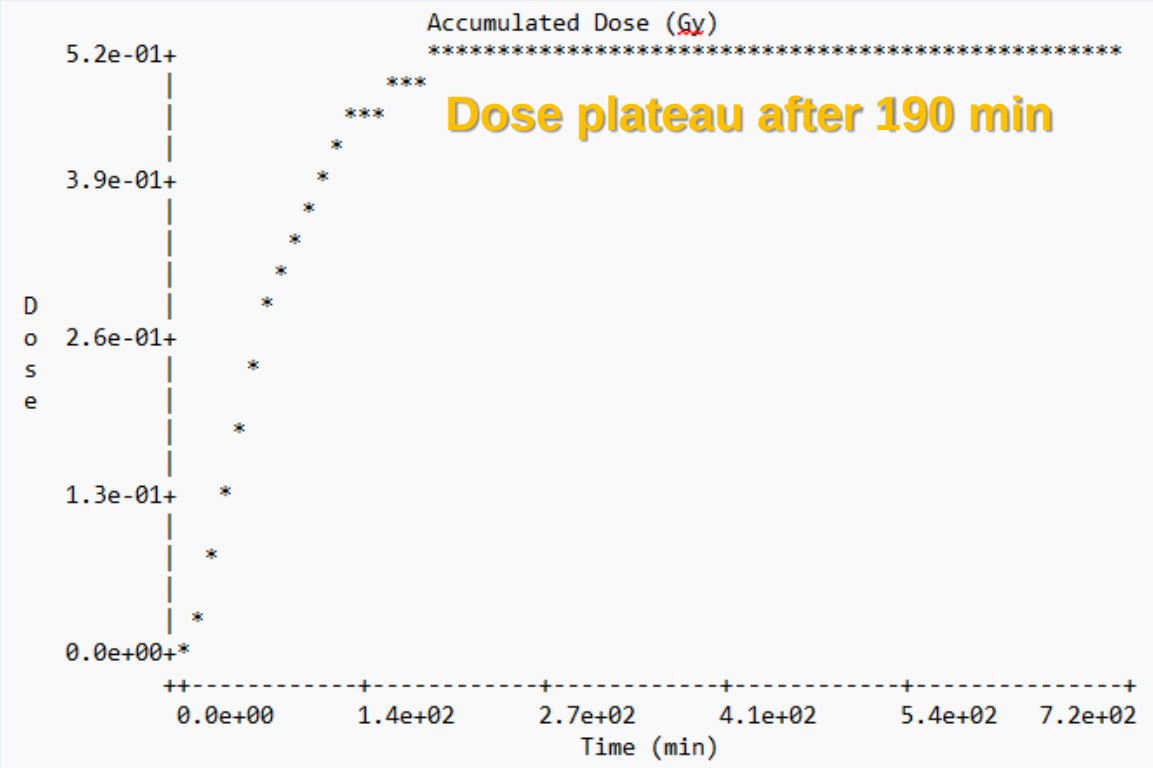
^{131}I 0.65 Gy to ROI Physical half-life 192 h



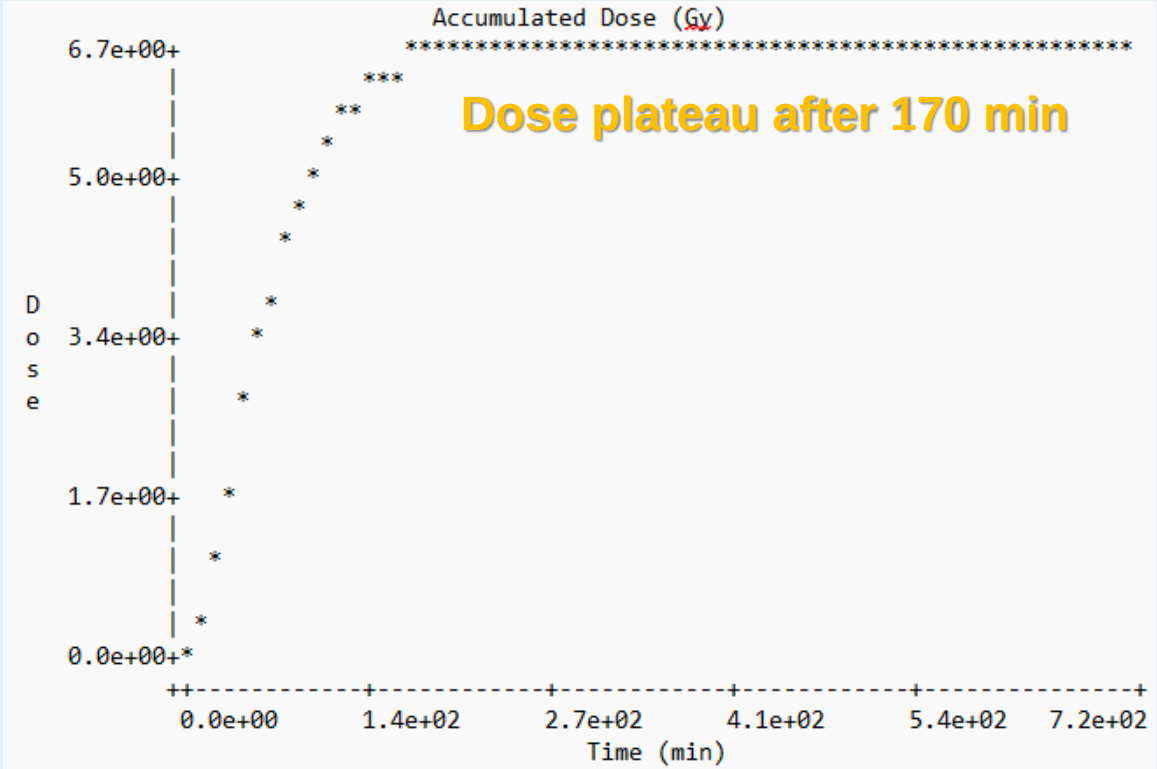
5-mCi Activity in Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.1 cm^2/h

^{177}Lu 0.52 Gy to ROI Physical half-life 160 h



^{211}At 6.7 Gy to ROI Physical half-life 7.2 h



Comparing Dose to ROI for different radionuclides

5-mCi Activity in Extravasated Fluid with Lateral Transmissivity 0.1 cm^2/h

Nuclide	Dose to ROI (Gy)
^{18}F	0.52
^{99m}Tc	0.01
^{90}Y	0.38
^{131}I	0.65
^{177}Lu	0.52
^{211}At	6.7

from ICRP-107 (2008)

			Emitted energy (MeV/nt)			
Nuclide	Half-life	Decay mode	Alpha	Electron	Photon	Total
F-18	109.77 m	ECB+	–	0.2416	0.9886	<1.2302*
Tc-99m	6.015 h	ITB-	–	0.0162	0.1266	<0.1428*
Y-90	64.10 h	B-	–	0.9331	<E-04	<0.9331*
I-131	8.02070 d	B-	–	0.1918	0.3828	<0.5746*
Lu-177	6.647 d	B-	–	0.1479	0.0351	0.1830
At-211	7.214 h	ECA	2.4998	0.0059	0.0367	2.5424

Small ROI energy deposition fraction for annihilation photons

Photon escape fraction reduces impact of total on ROI dose

Small ROI energy deposition fraction for high-energy electrons

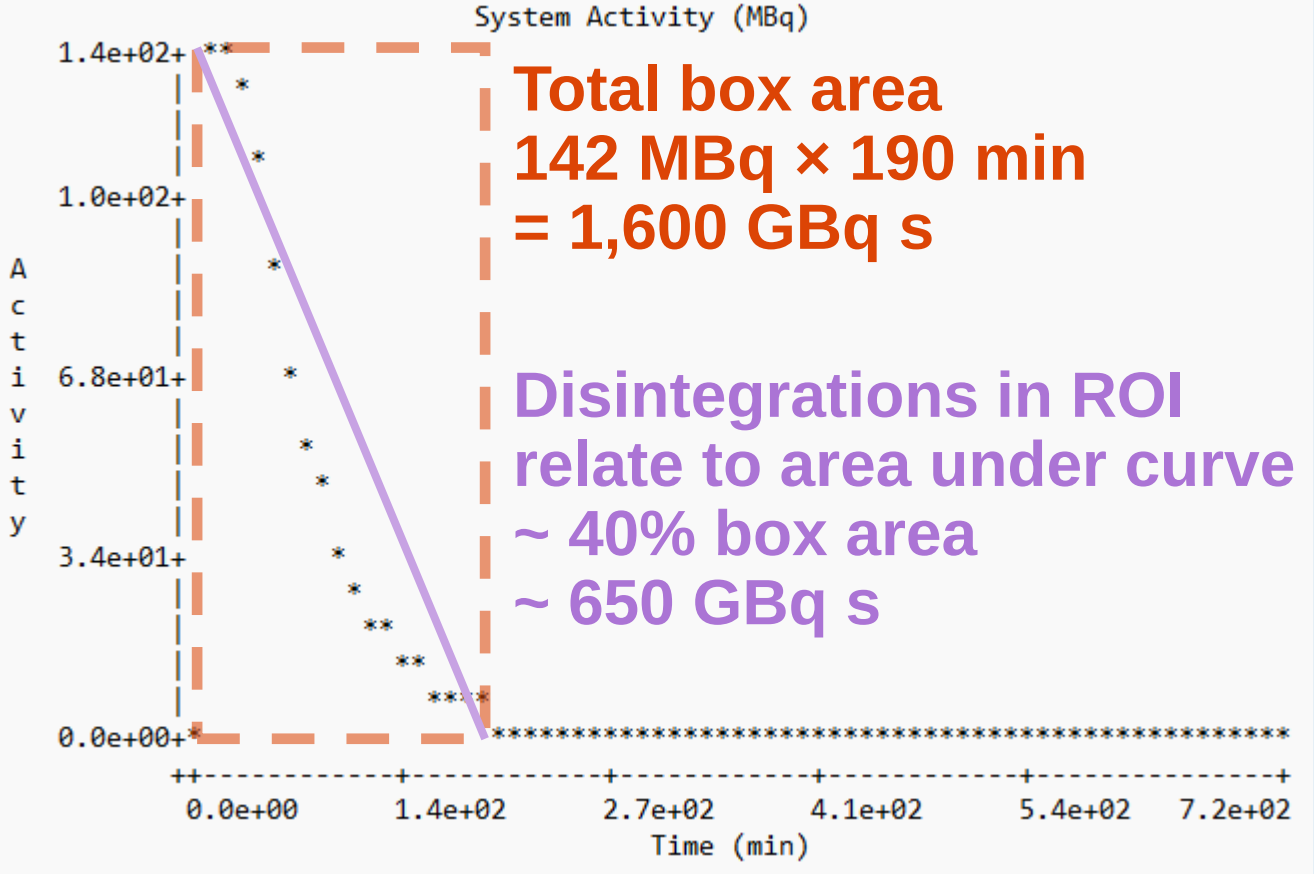
Photon escape fraction reduces impact of total on ROI dose

Largest energy deposition per disintegration

- Geometric influences on particle escape from ROI volume advised for most radionuclides
- No so important for At-211 due to limited alpha particle escape

Deep dive into ^{18}F example dose calculation

- **Begin with graphical approach using Text Report plot**
- **Area under activity curve represents activity delivering dose to tissue ROI**



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ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Determination of ^{18}F Positron Range in PET Imaging using Monte Carlo Simulation – Geant4 Code

Shayma Mohammed* and Adel Trabelsi

^{18}F positron range publication

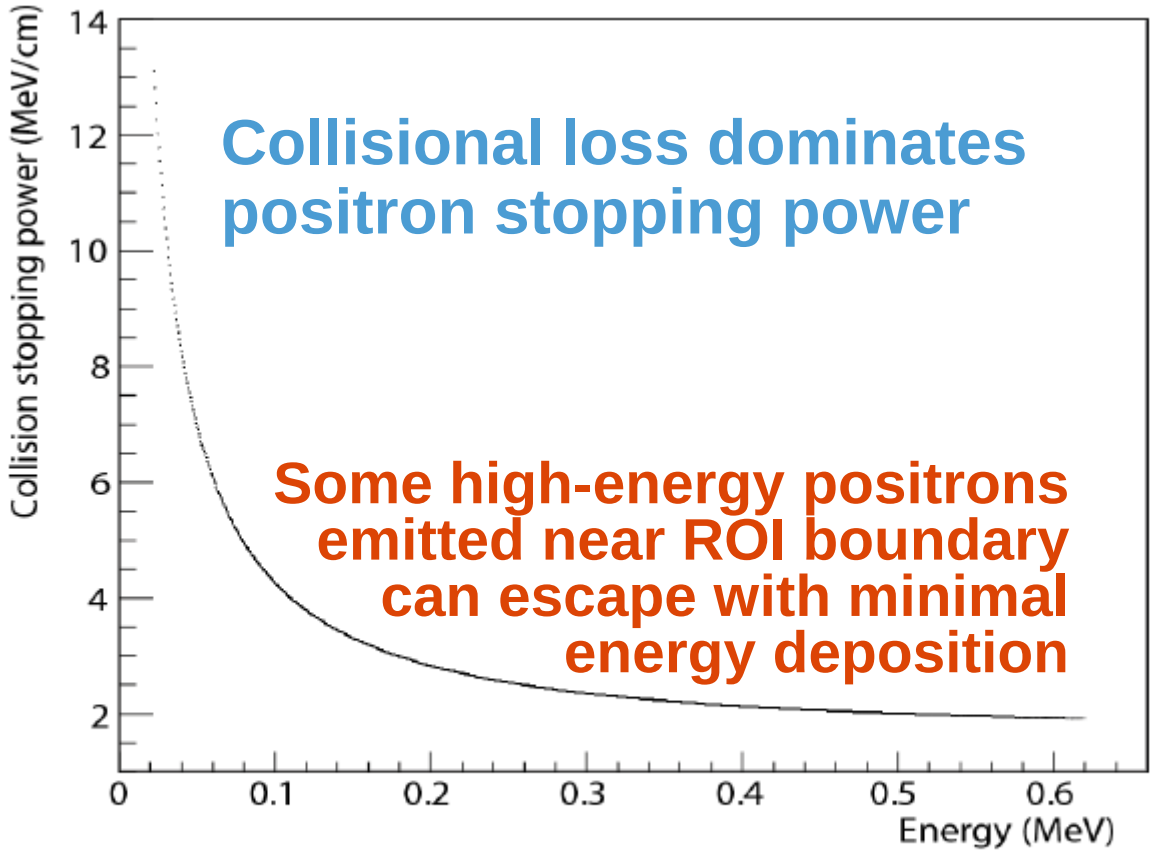


Figure 4. Shows the water collision energy loss values for 50000 ^{18}F tracks[24].

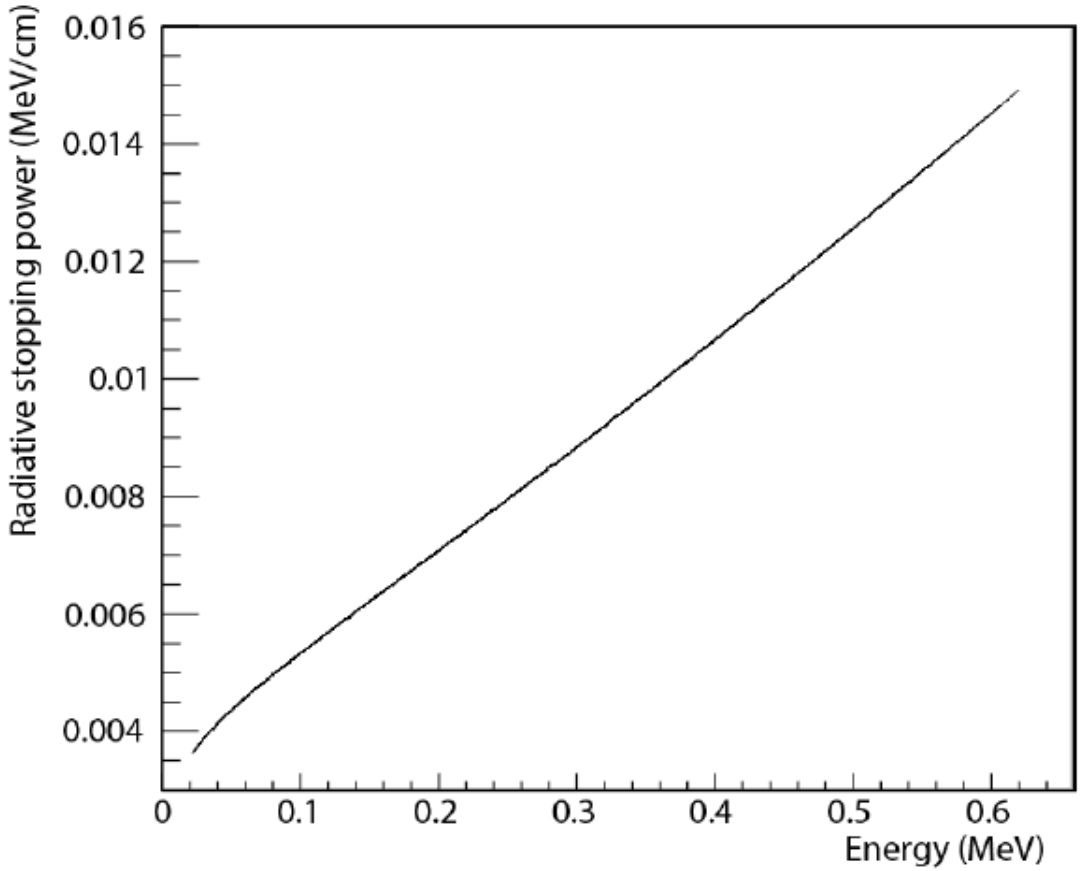


Figure 5. Shows the radiative energy loss values of the water for 50000 ^{18}F tracks[24].

^{18}F energy & range spectra from same publication

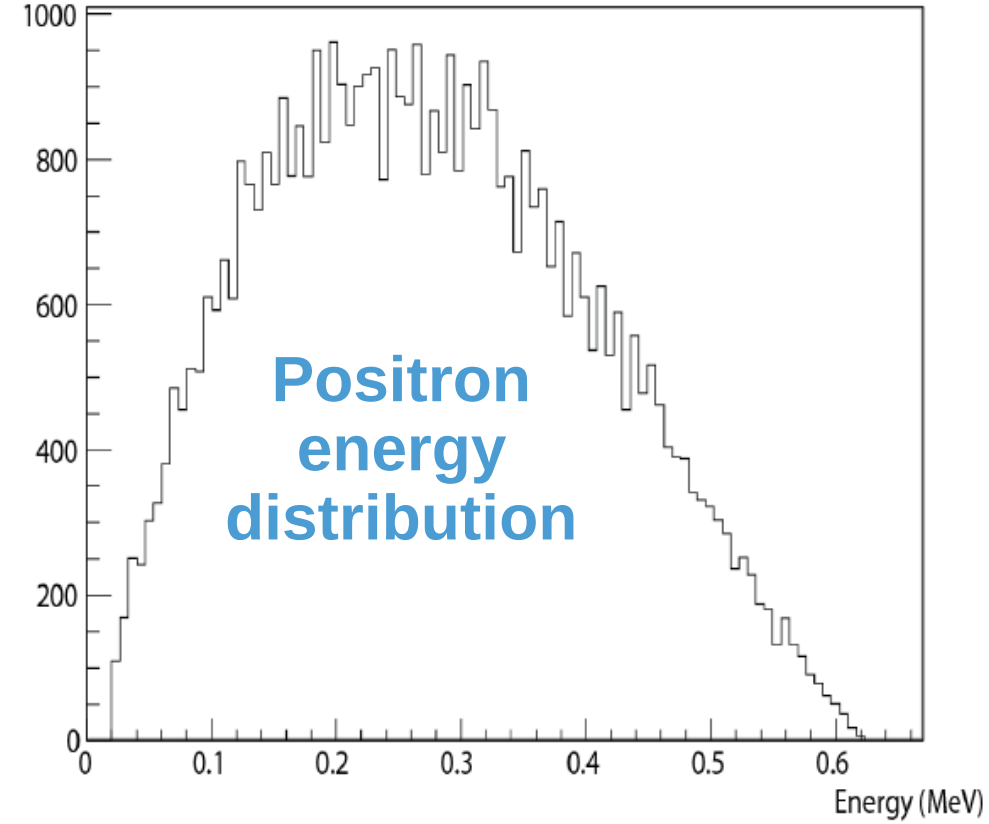
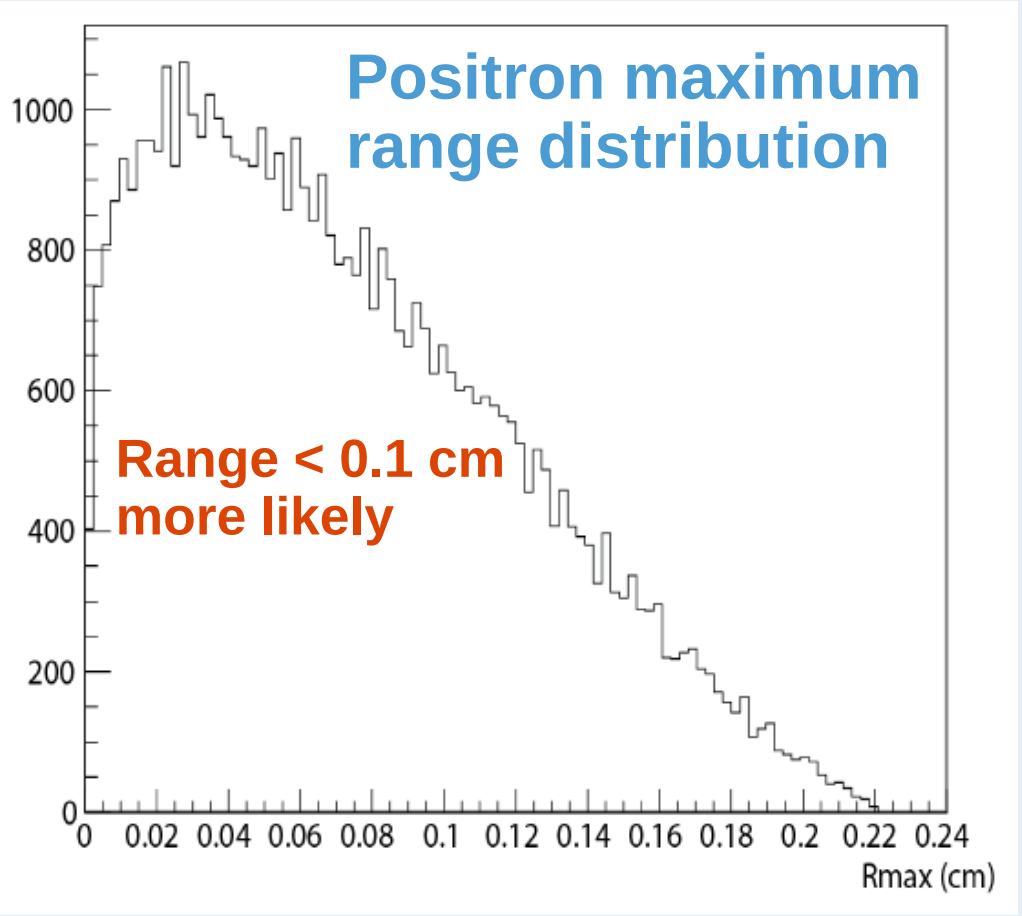


Figure 1. The positron energy Spectrum for ^{18}F located in water (50000 simulated positron trajectories) using the G4 UniformRand() random function.



For 0.8-cm thickness, some higher-energy positrons will escape the ROI.

Approximate ^{18}F positron energy fraction deposited in ROI

For the *more probable* R_{max} ≈ 0.1 cm for ^{18}F positrons, the ROI volume fraction for *mostly complete* positron self absorption is approximated as

$$1 - \frac{4.6 \times 7.8 \times 0.6}{4.8 \times 8.0 \times 0.8} = 0.70$$

This leaves 30% ROI volume for which positron escape is more important. By assuming 50% energy escape for this outer volumetric layer, **positron energy deposition in the ROI is approximated to be 85% of the total**.

Additionally, 10% energy deposition in ROI is assumed for annihilation photons.

from ICRP-107 (2008)

			Emitted energy (MeV/nt)			
Nuclide	Half-life	Decay mode	Alpha	Electron	Photon	Total
F-18	109.77 m	ECB+	–	0.2416	0.9886	1.2302

$$(0.24 \times 0.85) + (0.10 \times 0.1) \approx \mathbf{0.21} \frac{\mathbf{MeV}}{\mathbf{Bq\ s}}$$

Approximate ^{18}F energy deposited in ROI

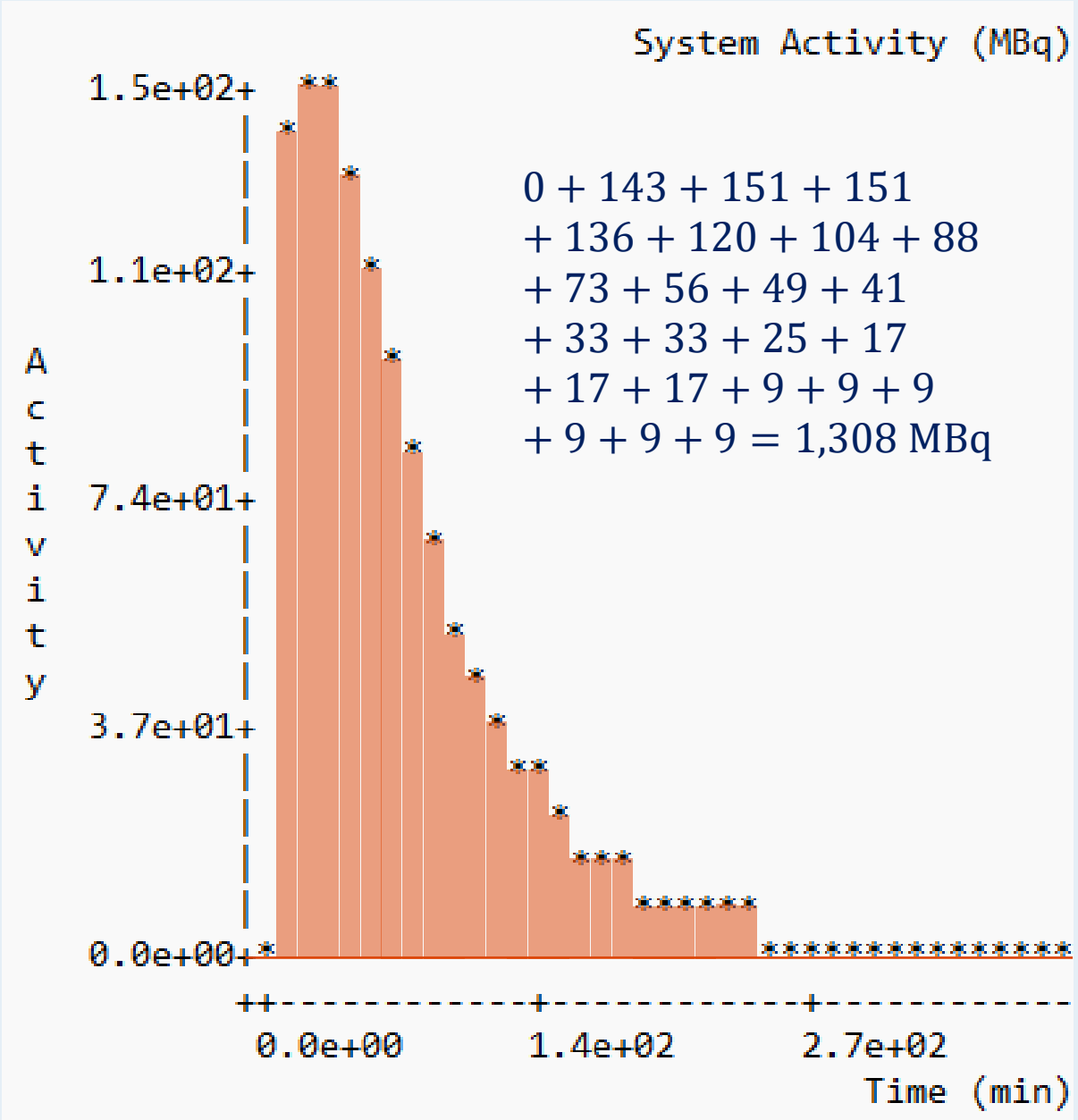
^{18}F Dose to ROI implied by prior approximations

$$D_{ROI} \approx \frac{650 \times 10^9\ Bq\ s\ \times 0.21 \frac{MeV}{Bq\ s}}{(4.8\ cm \times 8.0\ cm \times 0.8\ cm)\left(1.1\ \frac{g}{cm^3}\right)\left(6.24\ \times 10^9\ \frac{MeV}{Gy\ g}\right)} \approx 0.64\ Gy$$

V+ result: 0.52 Gy

19% lower dose

^{211}At Dose to ROI



Area under curve equals disintegrations in ROI

$$(\mathbf{1,308\ MBq})\left(\frac{\mathbf{10\ min}}{\mathbf{time\ step}}\right)\left(\frac{\mathbf{60\ s}}{\mathbf{1\ min}}\right) = \mathbf{785}\ \boldsymbol{GBq\ s}$$

- Begin with Text Report plot
- Calculate area under activity curve
- Calculate Dose to ROI (next slide)
  - Dose from parent radioactive emissions only
  - Dose from decay progeny presently not included

^{211}At Dose to ROI (parent emissions only)

$$D_{ROI} \approx \frac{\left(785 \times 10^9\ Bq\ s\right) \times \left(2.5\ \frac{MeV}{Bq\ s}\right)}{\left(4.8\ cm \times 8.0\ cm \times 0.8\ cm\right)\left(1.1\ \frac{g}{cm^3}\right)\left(6.24\ \times 10^9\ \frac{MeV}{Gy\ g}\right)} \approx 9.3\ Gy$$

V+ result: 6.7 Gy

27% lower dose

Example VII: Larger volume extravasation with limb elevation including voxel size insights

Example VII: 45-min ^{177}Lu extravasation with 120-min limb elevation & many parameter defaults

Extravasation Dosimetry v1.0

File Mode Help

V+ Extravasation Dosimetry v1.0

MODEL INPUTS

Source and Concentration Inputs

Database: ICRP-38 ICRP-107

Nuclide: Lu-177

Concentration: 300.000 MBq/mL

Flow Rate: 0.400 mL/min

Layer Inputs

Tissue Model: Homogeneous Heterogeneous

Number of Layers: 1

Layer 1

Effective Tissue Thickness: 5.000 mm

Lateral Transmissivity: 3.000 cm²/h

Transport Inputs

Dose Notification Threshold: 2.000 Gy

Region Width: 7.000 cm

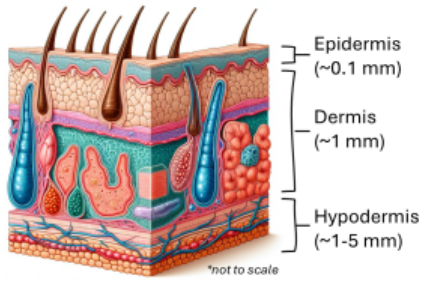
Region Length: 7.000 cm

Vertical Transmissivity: 1.000 cm²/h

Fluid Diffusivity: 0.100 cm²/h

Voxel Side Length: 5.000 mm

Diagram



Timeline Calculate Results

Extravasation Timeline

V+ Extravasation Dosimetry v1.0

EVENT INPUTS

#	Event	Day	Start Time	End Time	Duration (hr)
1	Extravasation	1	12:00AM	12:45AM	0.75
2	Limb Elevation	1	12:45AM	02:45AM	2.00
3	Analysis Period	1	12:00AM	04:00AM	4.00

Add/Delete Events

Add Event Delete Selected Event

Edit Selected Event (#2)

Type: Limb Elevation

Day

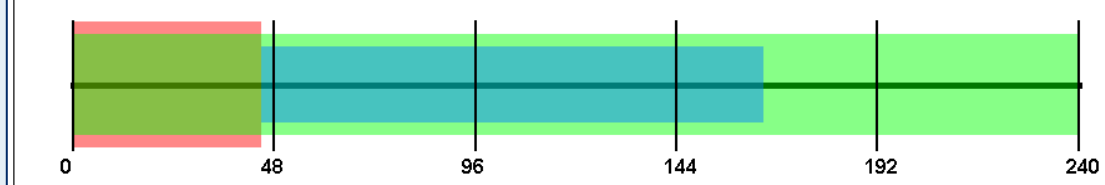
Start Time: 12:45 AM 1

End Time: 02:45 AM 1

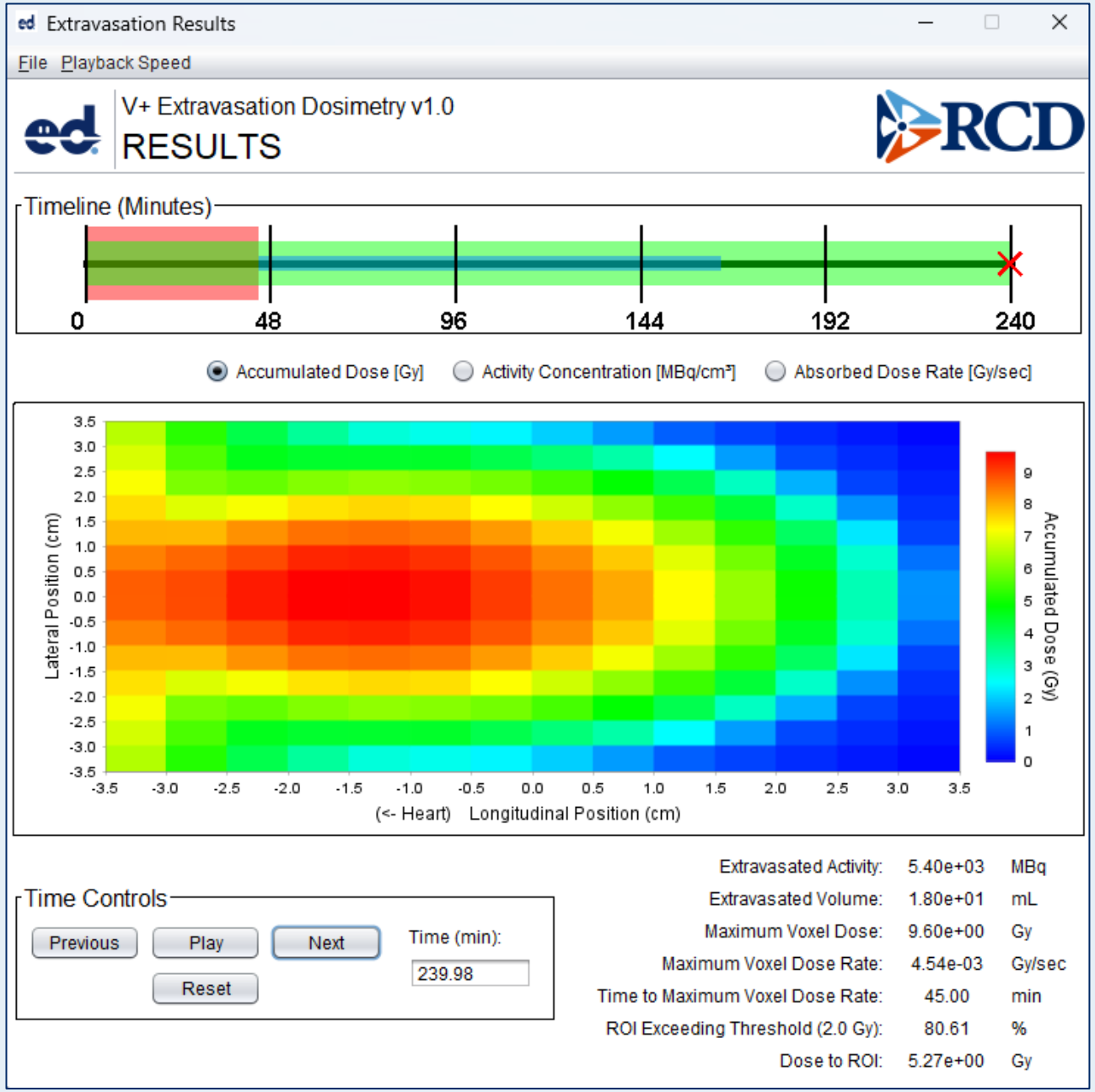
Duration: 2.00 Hours

Elevation: 70.0 Degrees

Timeline (Minutes)



V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/



Gravity from limb elevation influences fluid movement and accumulated dose distribution

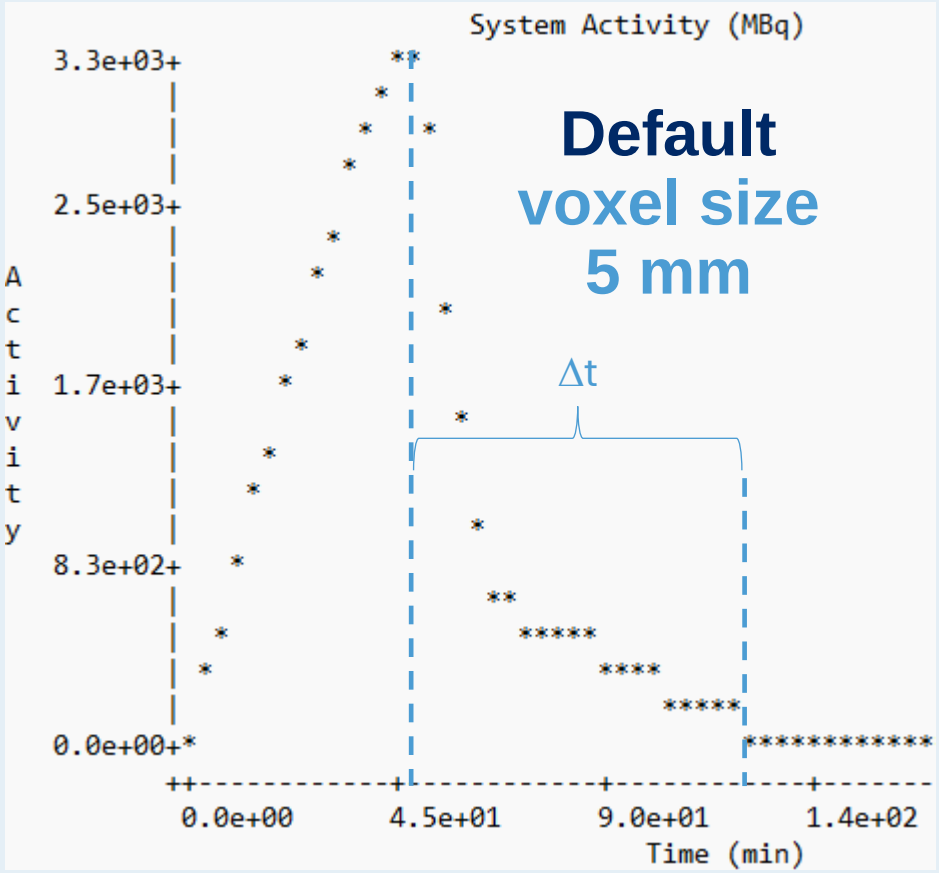
Elevated end

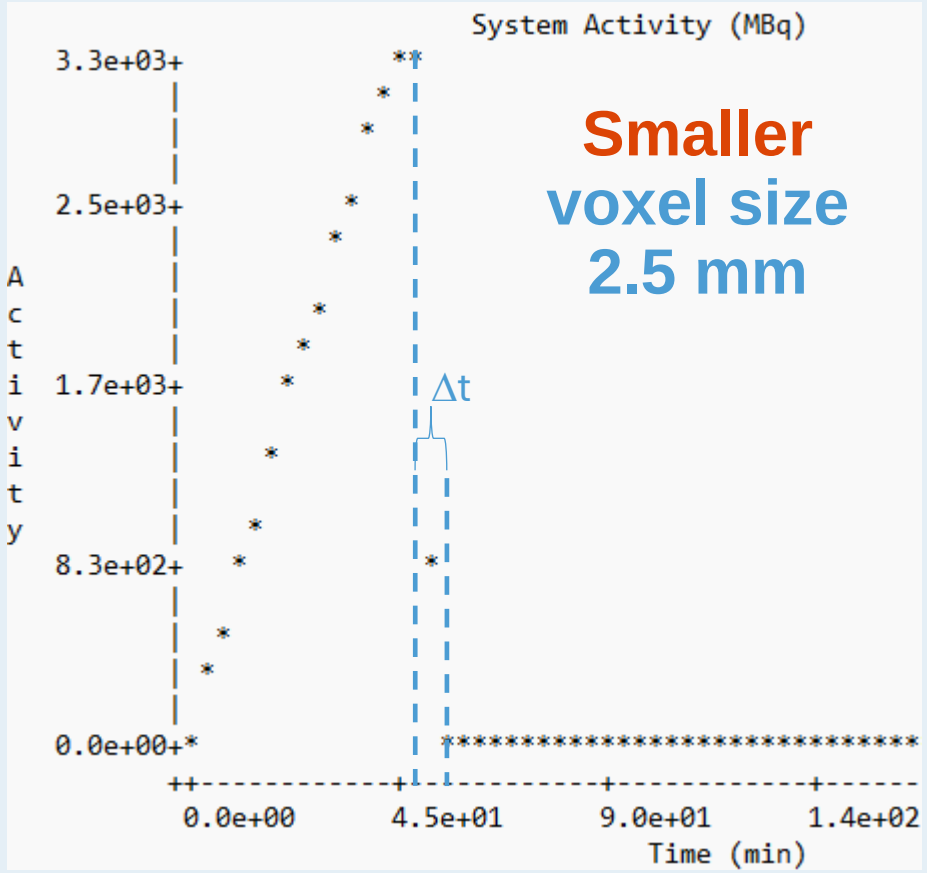
Noticeable shift in maximum dose from extravasation centroid at (0,0)

V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/

Voxel size “influence” on lateral flow & biological clearance

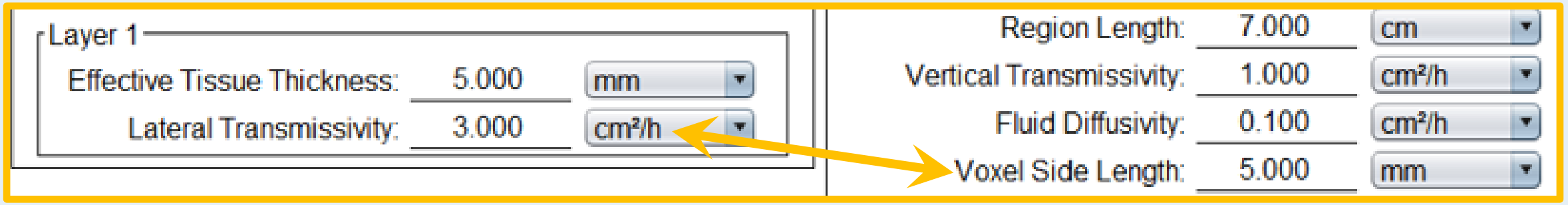
- 5 mm (default): Nearly complete depletion of ROI activity in ~70 min
- 2.5 mm (caution for small sizes): Nearly complete depletion in 7 min

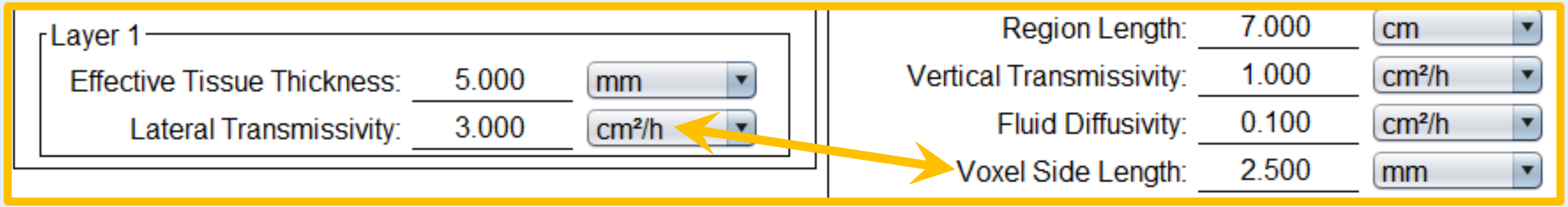




V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/

Voxel size "influence" on lateral flow & biological clearance (cont'd)





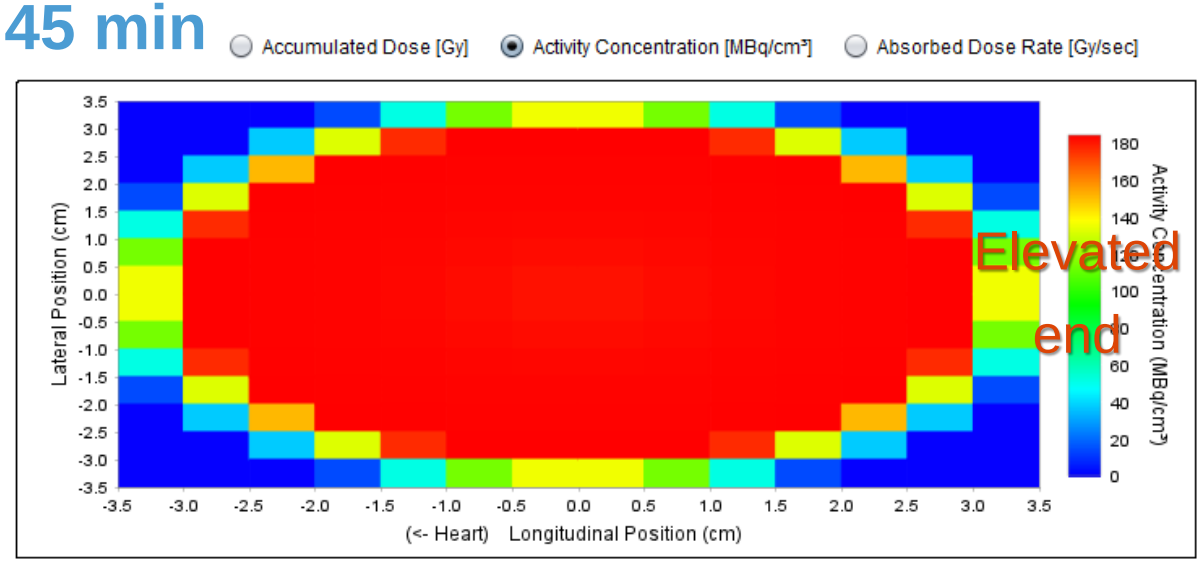
Transmissivity & diffusivity input values currently applied to voxel (not tissue layer)

- **Note this codependency**
- **Real influence from parameter associations**
- **Adjust transmissivity & diffusivity for voxel size to obtain similar flow behavior (presently)**
  - **Potential code modification may link these input definitions to a unit computational volume**

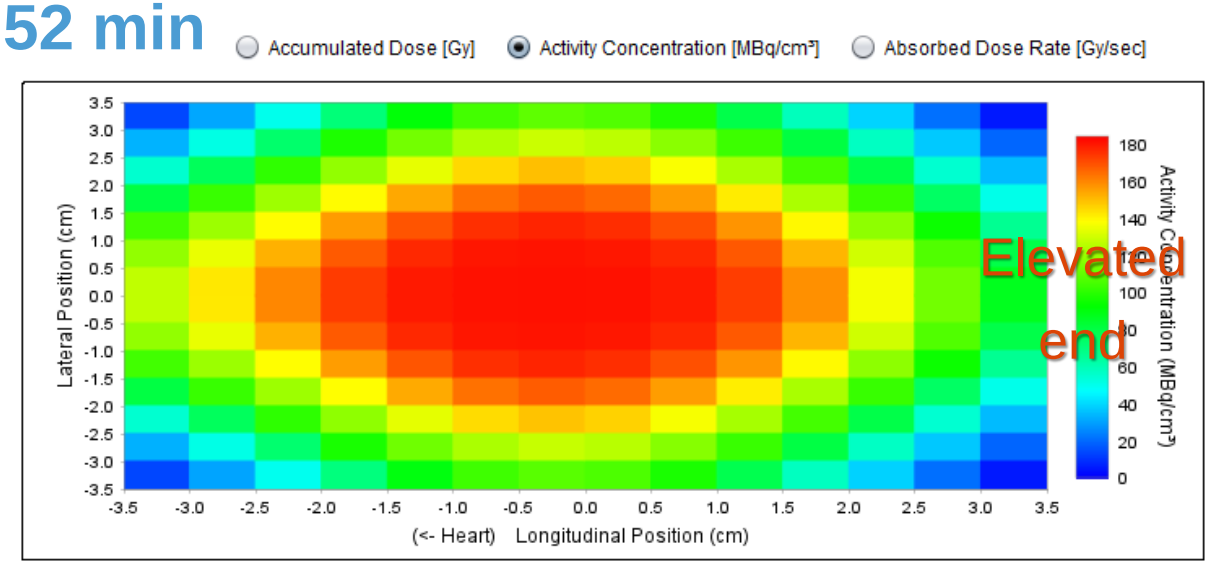
5-mm default voxels yield minimal ROI depletion in 7 min

Activity Concentrations

45 min



52 min

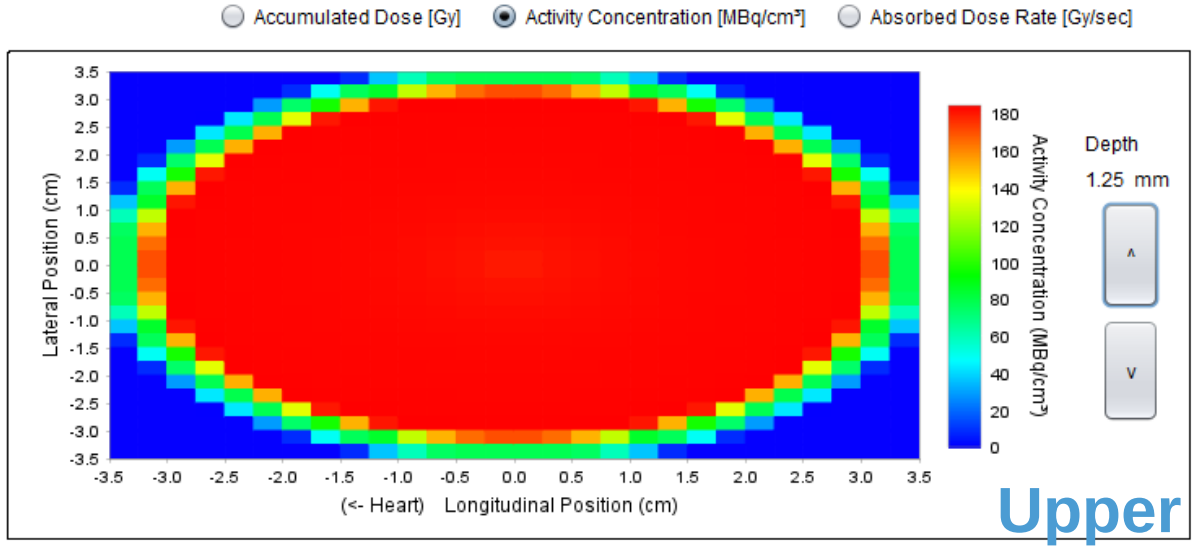


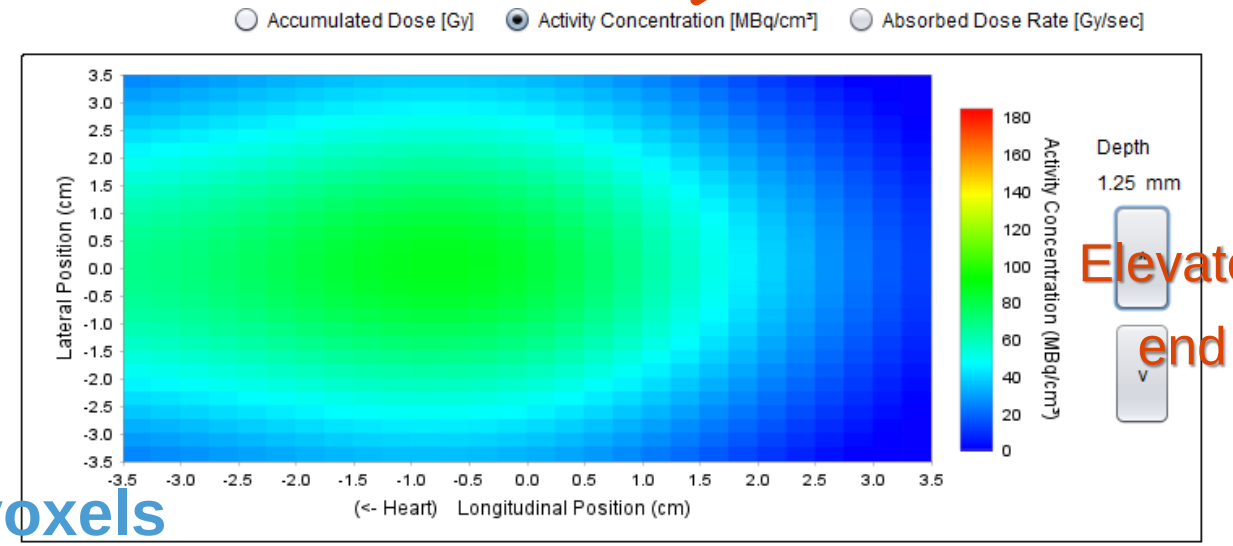
2.5-mm voxels yield substantial ROI depletion in 7 min

Activity Concentrations

45 min

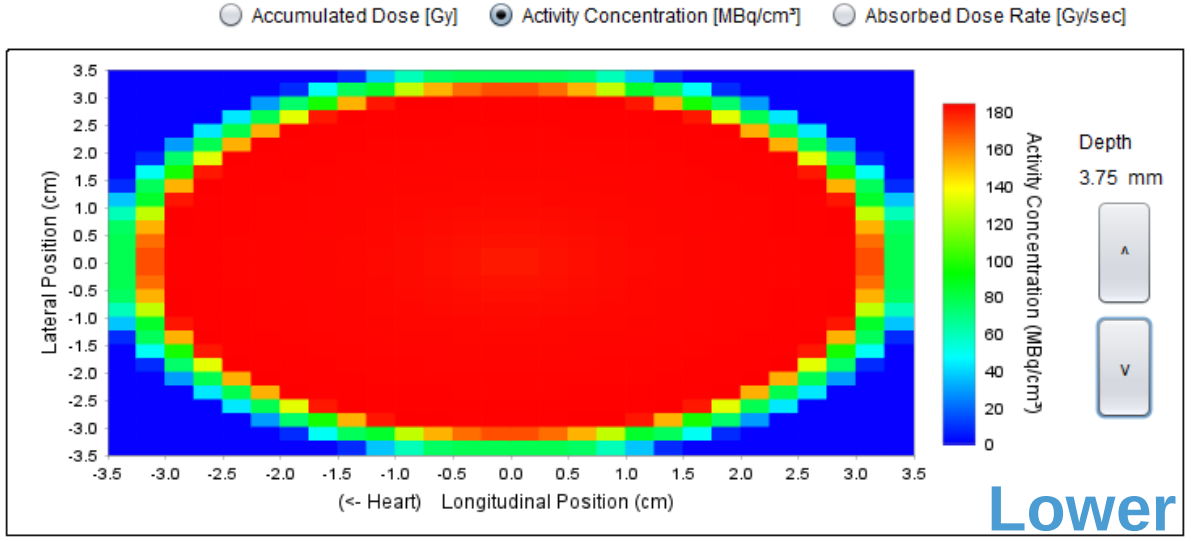
52 min

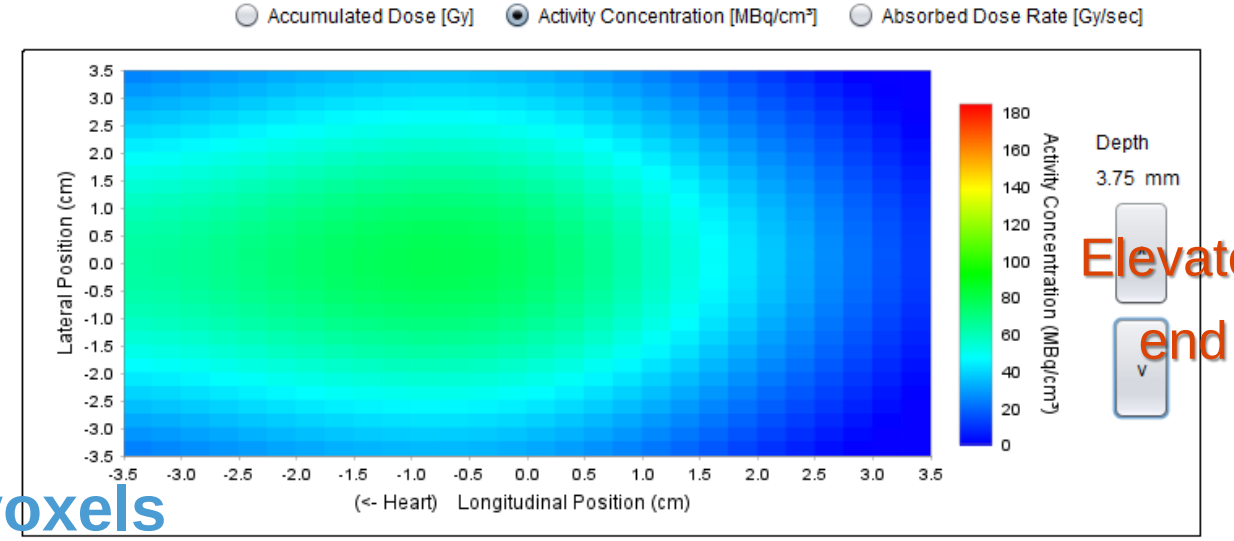




Elevated end

Upper voxels





Elevated end

Lower voxels

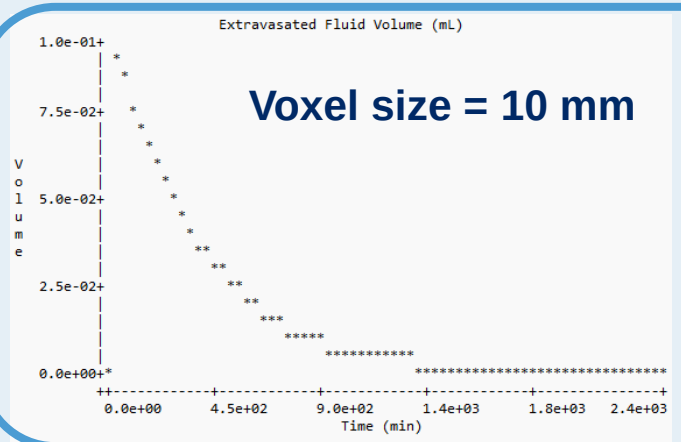
V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/

5. Voxel Size Effects

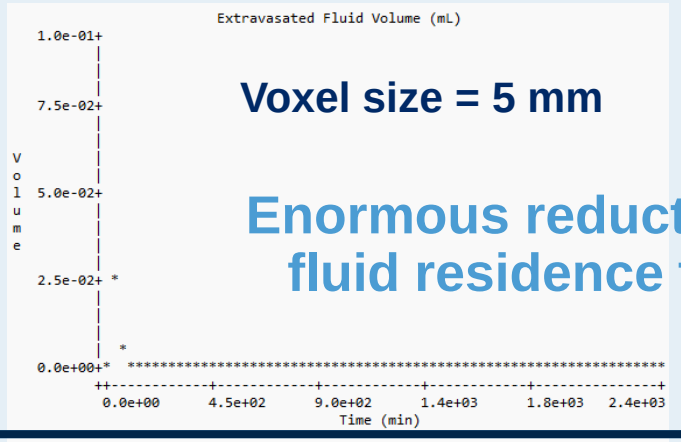
Voxel size effect on diffusion dominated test case

Simulation 1: Voxel Size = Effective Thickness

Simulation 2: Voxel Size = ½ Effective Thickness



Voxel size = 10 mm

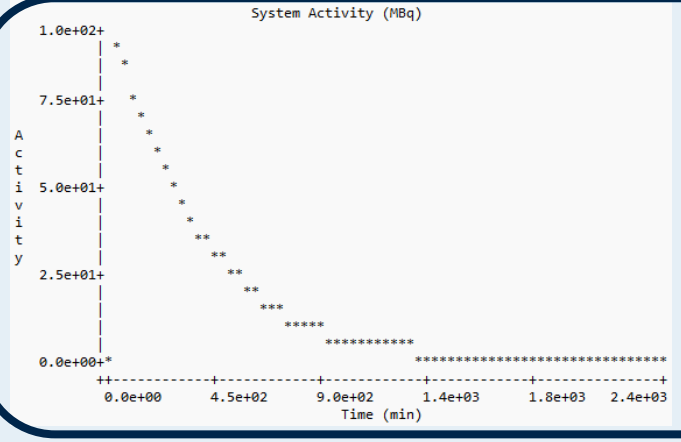


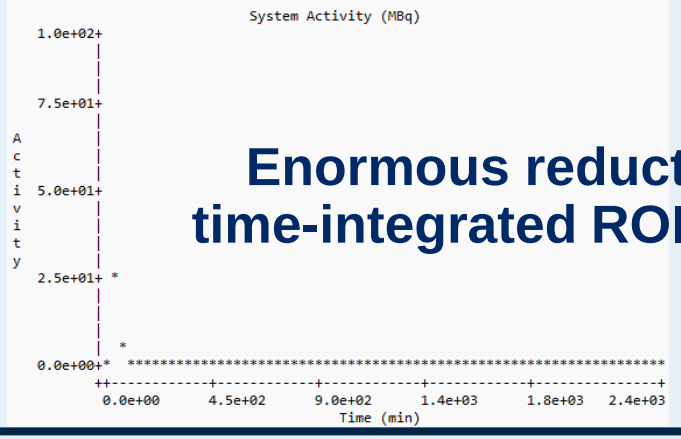
Voxel size = 5 mm

Enormous reduction in fluid residence time

→ **2x reduction in voxel size**

→ **7x reduction in clearance half-time**





Enormous reduction in time-integrated ROI activity

Outputs

Max Voxel Dose:	1.46e+00	Gy
Max Voxel Dose Rate:	1.80e-04	Gy/s
Time to Max Voxel Dose Rate:	1.0	min
ROI Exceeding Dose Threshold:	0.0	%
Dose to ROI:	1.26e-01	Gy
Region Volume:	128.0	cm³

2x reduction

14x reduction

Outputs

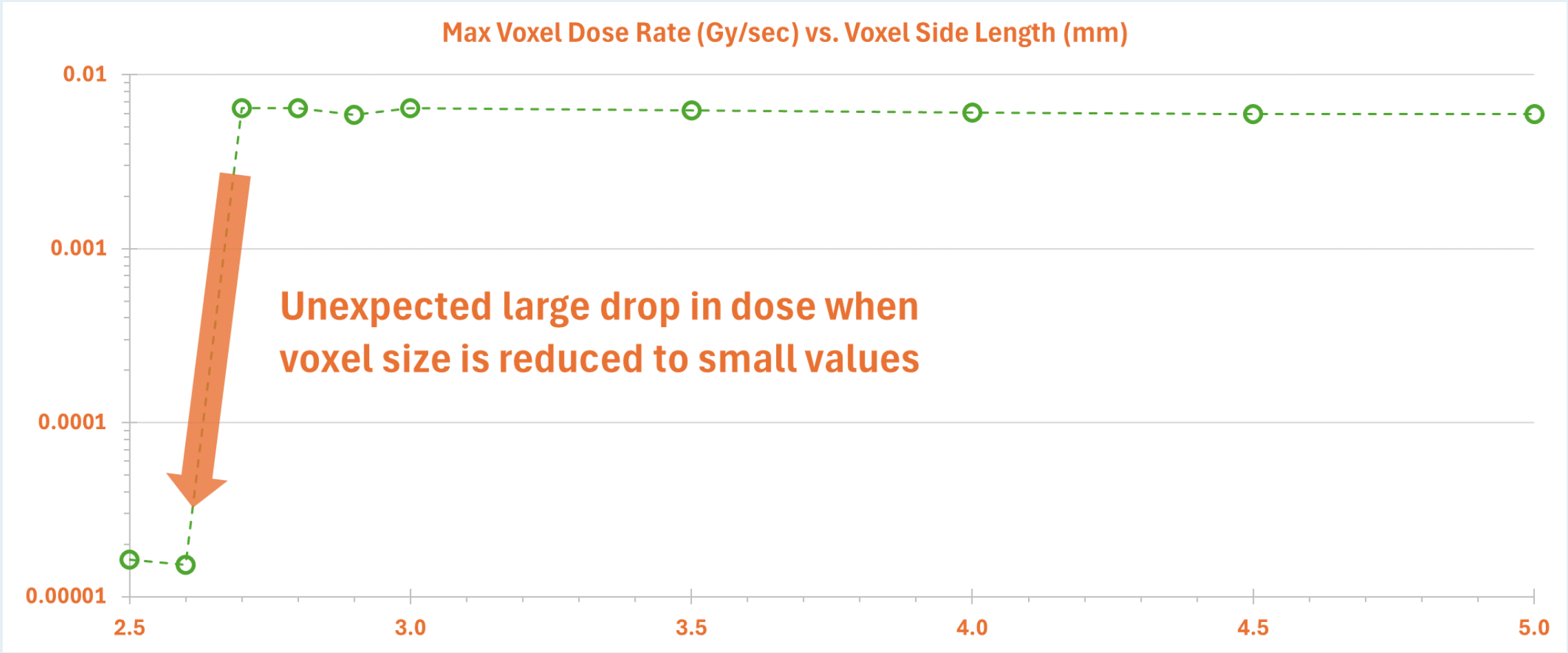
Max Voxel Dose:	8.47e-01	Gy
Max Voxel Dose Rate:	7.20e-04	Gy/s
Time to Max Voxel Dose Rate:	1.0	min
ROI Exceeding Dose Threshold:	0.0	%
Dose to ROI:	8.84e-03	Gy
Region Volume:	128.0	cm³

V+ software is available from U.S. NRC RAMP https://ramp.nrc-gateway.gov/

Examine voxel size effects on dose

30-min ^{177}Lu extravasation

Same activity concentration
Similar ROI volumes
Same flow parameter values
Different voxel sizes



V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/

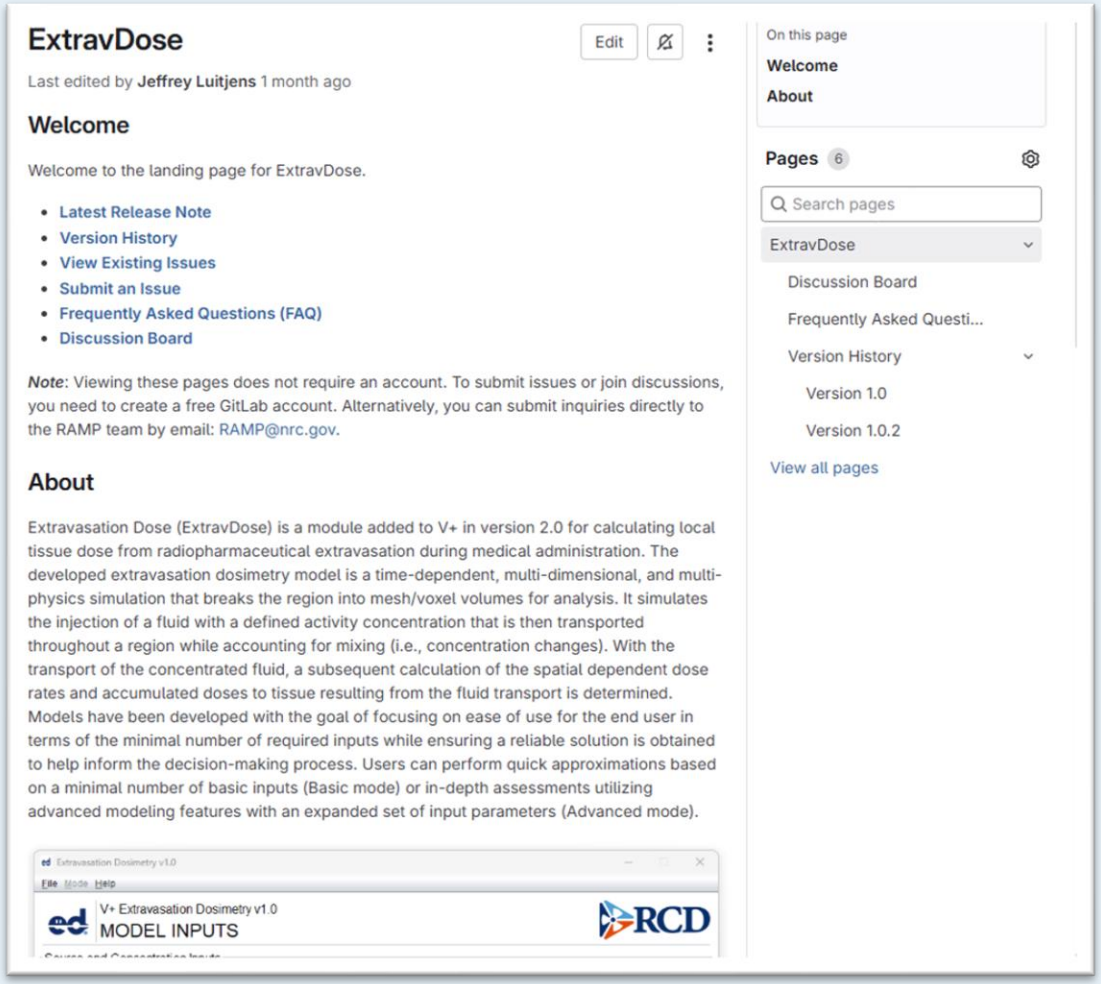
6. Reporting Errors & Posting Questions

User Engagement, Information, Help, and Issue Tracking

- GitLab is used to manage the configuration of ExtravDose.

https://gitlab.com/RCD-1/varskinplus/extravdose/-/wikis/home

- Latest Release Note
- Version History
- View Existing Issues
- Submit an Issue
- Frequently Asked Questions (FAQ)
- Discussion Board

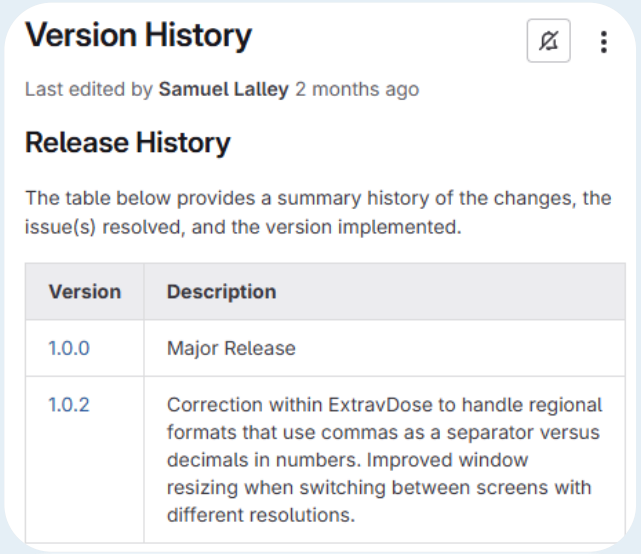


Version History – Levels of Detail

Summary of all versions

Details of a version

Details of a single change



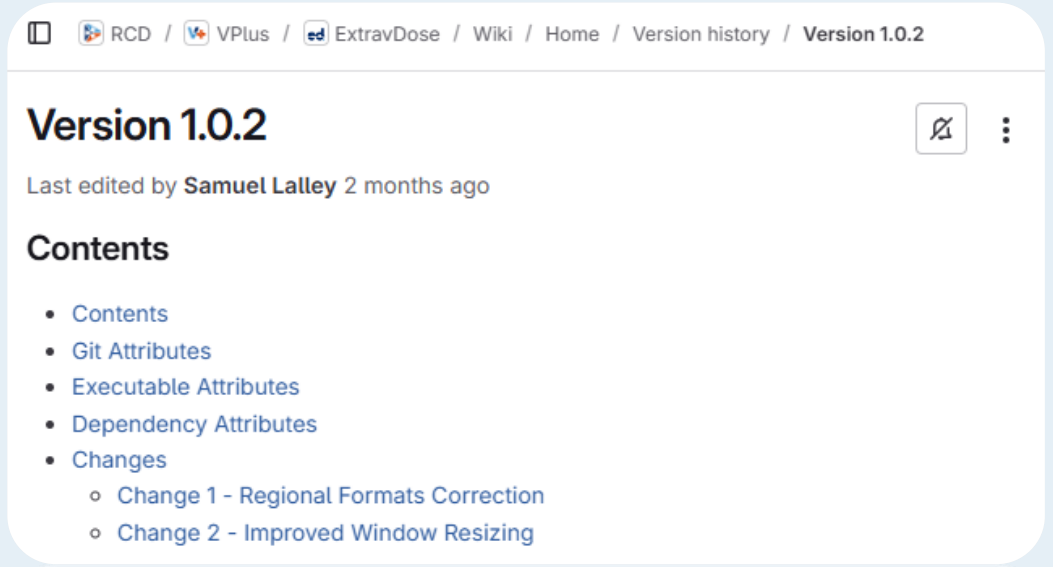
Version History

Last edited by **Samuel Lalley** 2 months ago

Release History

The table below provides a summary history of the changes, the issue(s) resolved, and the version implemented.

Version	Description
1.0.0	Major Release
1.0.2	Correction within ExtravDose to handle regional formats that use commas as a separator versus decimals in numbers. Improved window resizing when switching between screens with different resolutions.



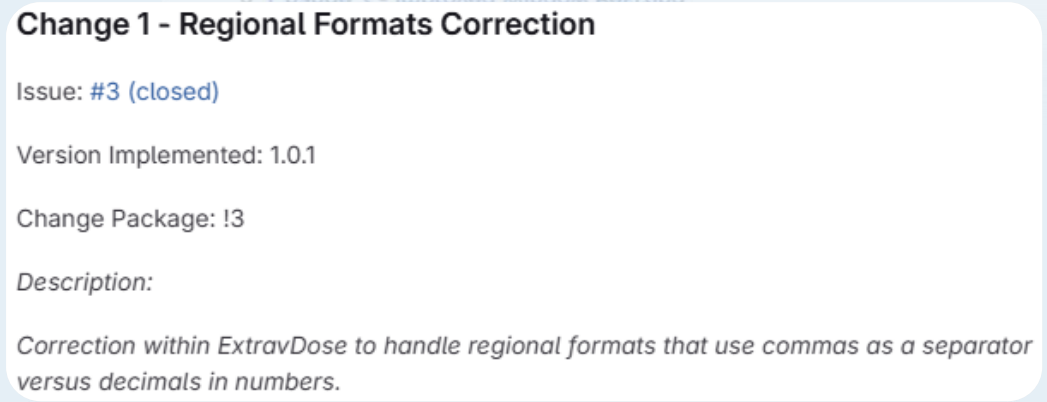
RCD / VPlus / ExtravDose / Wiki / Home / Version history / **Version 1.0.2**

Version 1.0.2

Last edited by **Samuel Lalley** 2 months ago

Contents

- Contents
- Git Attributes
- Executable Attributes
- Dependency Attributes
- Changes
  - Change 1 - Regional Formats Correction
  - Change 2 - Improved Window Resizing



Change 1 - Regional Formats Correction

Issue: #3 (closed)

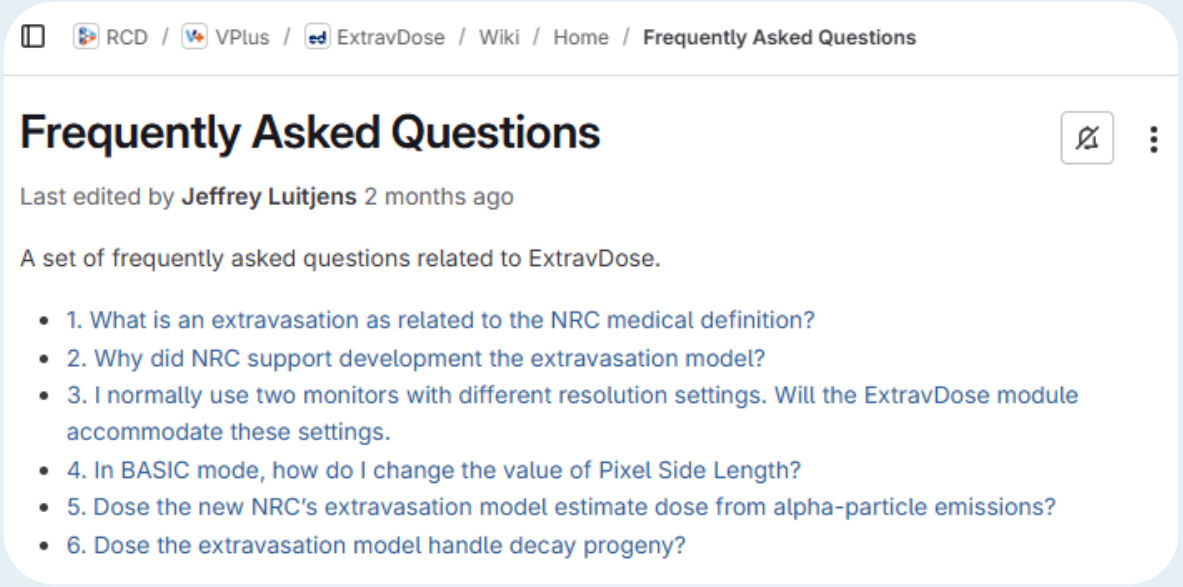
Version Implemented: 1.0.1

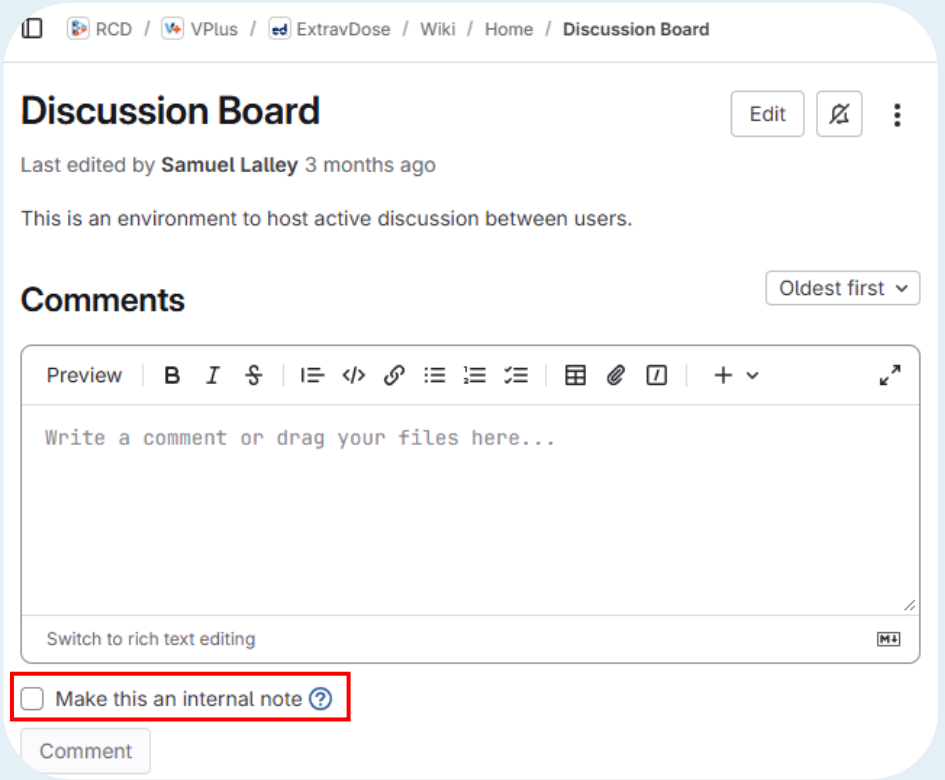
Change Package: !3

Description:

Correction within ExtravDose to handle regional formats that use commas as a separator versus decimals in numbers.

FAQs and Discussion Boards

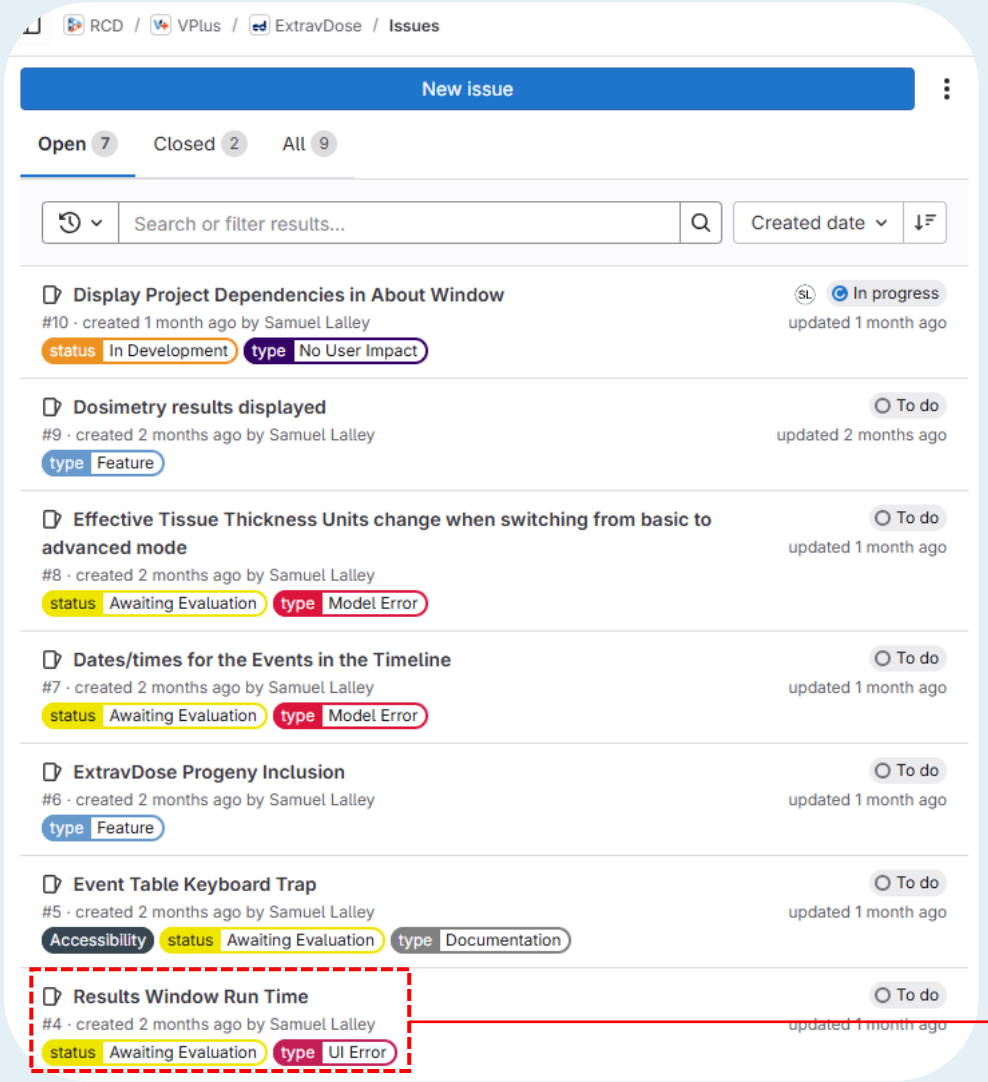


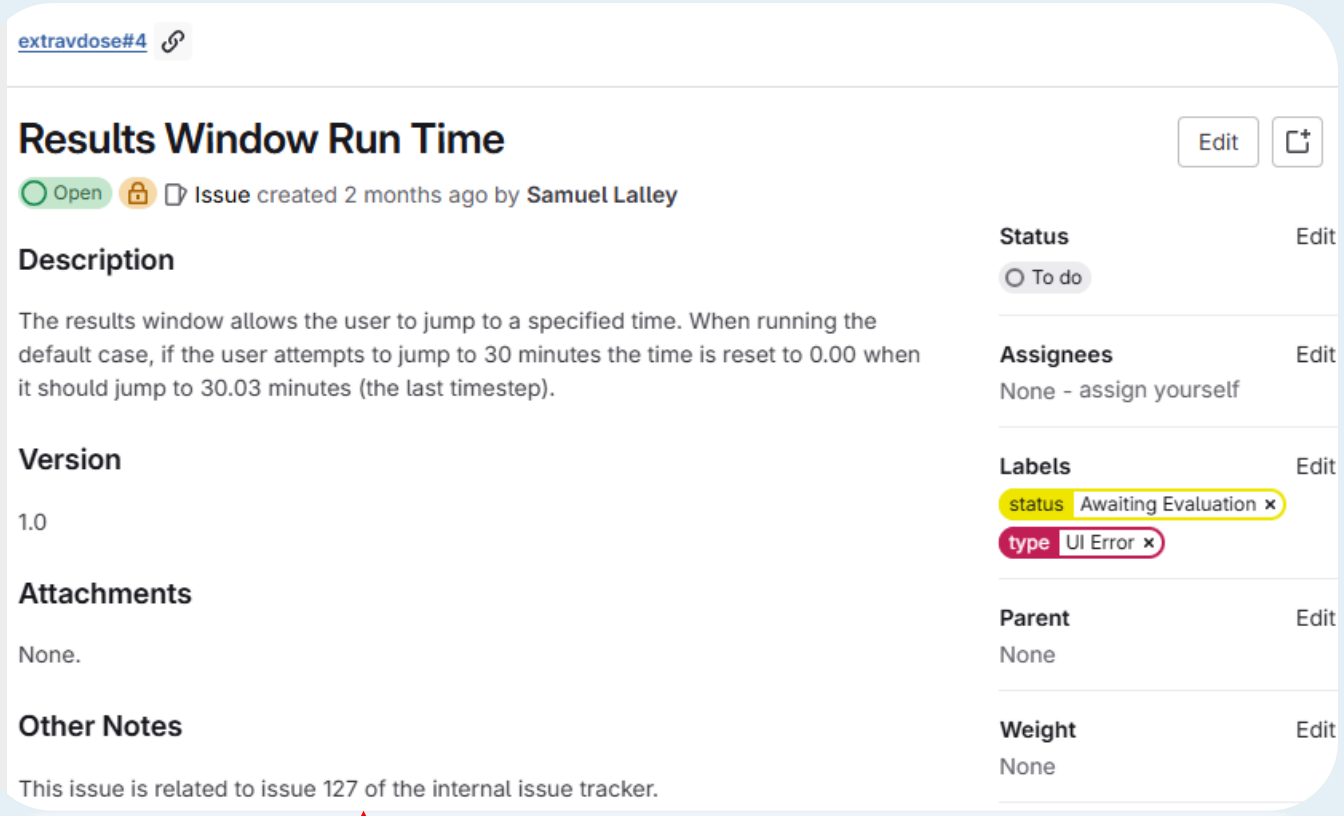


To submit information that only the developers can see check the box to make it an internal note.

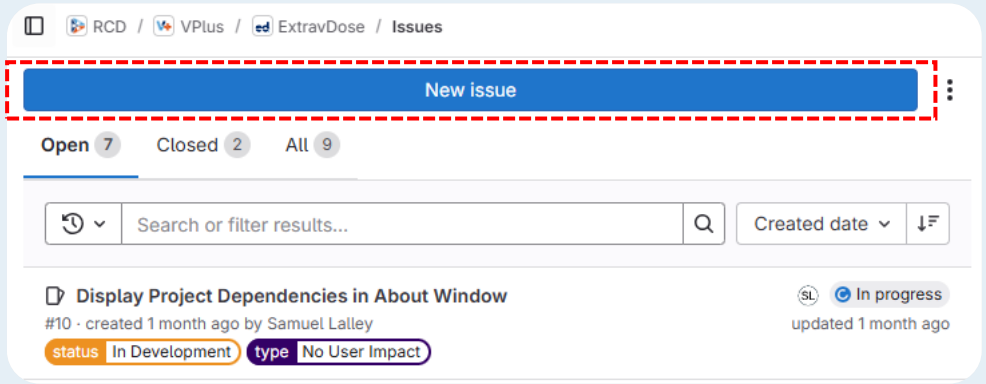
Viewing Issues

Anyone can view these and no account is required to do so.

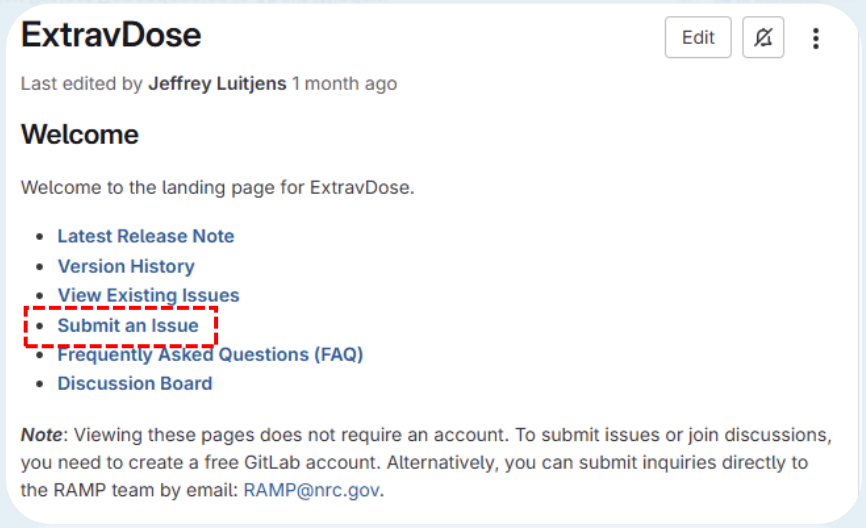


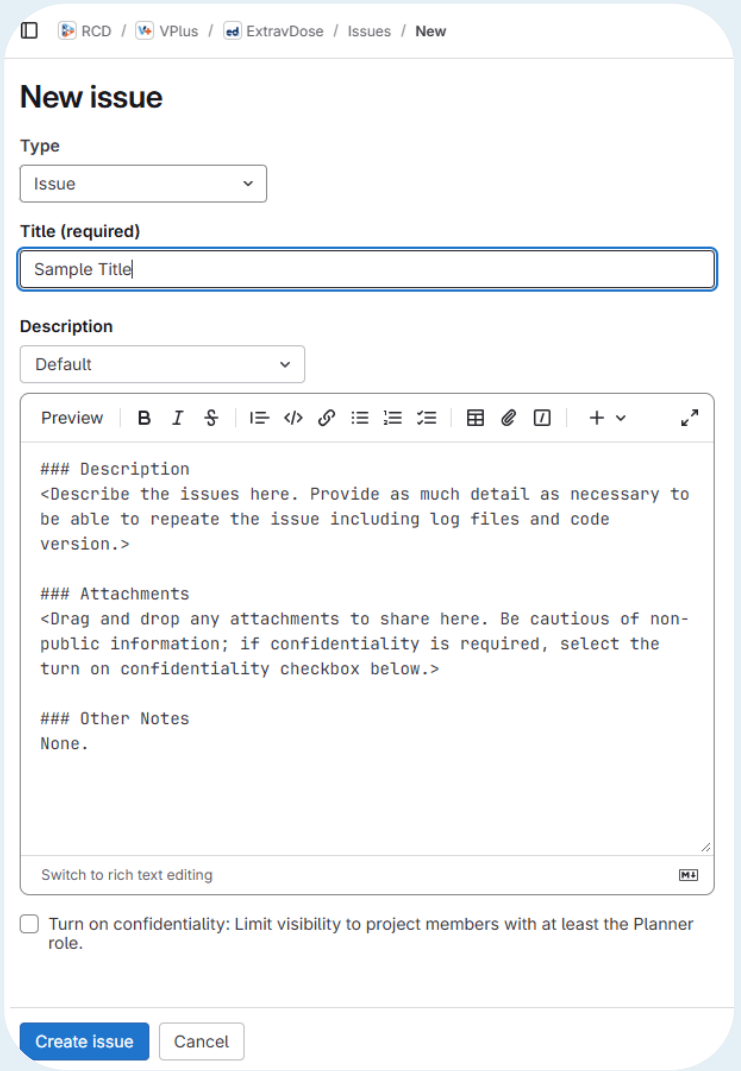


Submitting an Issue



or

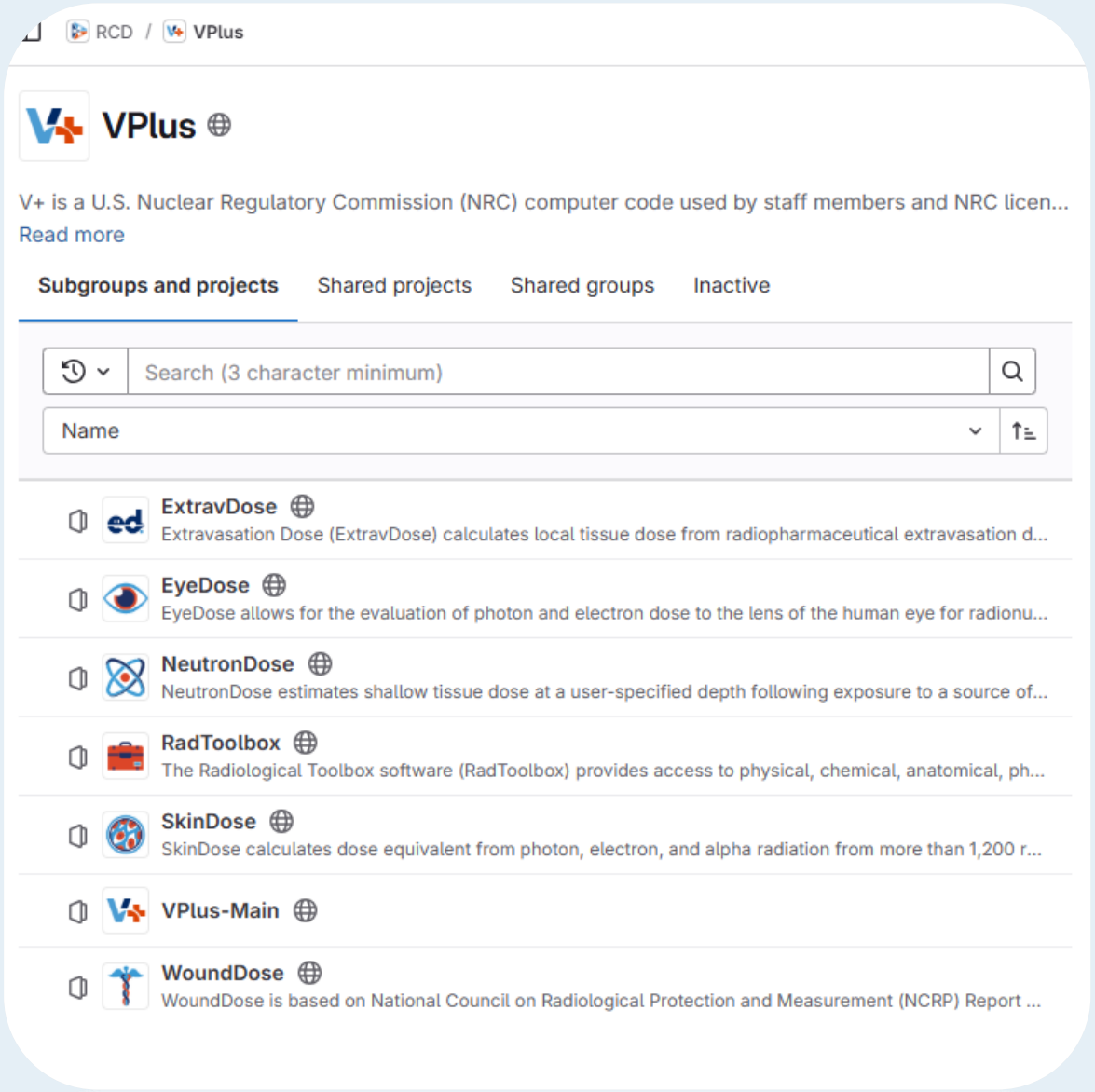




Note: Viewing these pages does not require an account.

To submit issues or join discussions, you need to create a free GitLab account.

Alternatively, you can submit inquiries directly to the RAMP team by email: RAMP@nrc.gov.



https://gitlab.com/RCD-1/varskinplus

V+ software is available from U.S. NRC https://ramp.nrc-gateway.gov/

End of Intermediate Training