



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**



Extravasation Dosimetry v1.0

File **Mode** Help

Basic
Advanced

Extravasation Dosimetry v1.0

MODEL INPUTS

Source and Concentration Inputs

Database: ICRP-38 ICRP-107 Concentration: 100.000 MBq/mL

Nuclide: Tc-99m Flow Rate: 1.000 mL/min

Layer Inputs

Tissue Model: Homogeneous Heterogeneous

Number of Layers: 2

Layer 1

Effective Tissue Thickness: 5.000 mm

Lateral Transmissivity: 3.000 cm²/h

Layer 2

Effective Tissue Thickness: 5.000 mm

Lateral Transmissivity: 3.000 cm²/h

Transport Inputs

Dose Notification Threshold: 2.000 Gy

Region Width: 10.000 cm

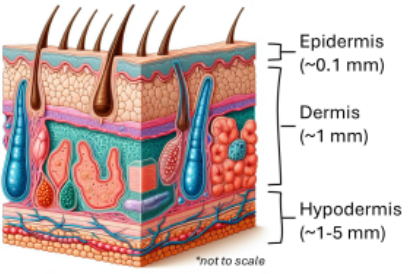
Region Length: 20.000 cm

Vertical Transmissivity: 1.000 cm²/h

Fluid Diffusivity: 0.100 cm²/h

Voxel Side Length: 5.000 mm

Diagram



Timeline Calculate Results

A proper timeline has not been specified.



Advanced Layer Inputs



Required for Advanced calculations

Homogeneous or Heterogeneous
Up to 4 layers

Enter Lateral Transmissivity
for each layer



Advanced Transport Inputs



ed Extravasation Dosimetry v1.0

File Mode Help

ed V+ Extravasation Dosimetry v1.0
MODEL INPUTS

RCD

Source and Concentration Inputs

Database: ICRP-38 ICRP-107 Concentration: 100.000 MBq/mL

Nuclide: Tc-99m Flow Rate: 1.000 mL/min

Layer Inputs

Tissue Model: Homogeneous Heterogeneous

Number of Layers: 2

Layer 1

Effective Tissue Thickness: 5.000 mm

Lateral Transmissivity: 3.000 cm²/h

Layer 2

Effective Tissue Thickness: 5.000 mm

Lateral Transmissivity: 3.000 cm²/h

Transport Inputs

Dose Notification Threshold: 2.000 Gy

Region Width: 10.000 cm

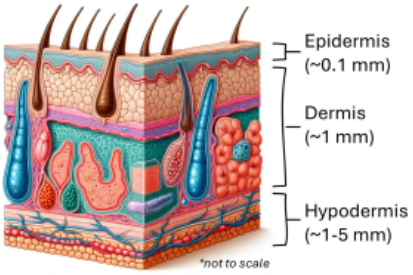
Region Length: 20.000 cm

Vertical Transmissivity: 1.000 cm²/h

Fluid Diffusivity: 0.100 cm²/h

Voxel Side Length: 5.000 mm

Diagram



Timeline Calculate Results

A proper timeline has not been specified.

Enter Vertical Transmissibility

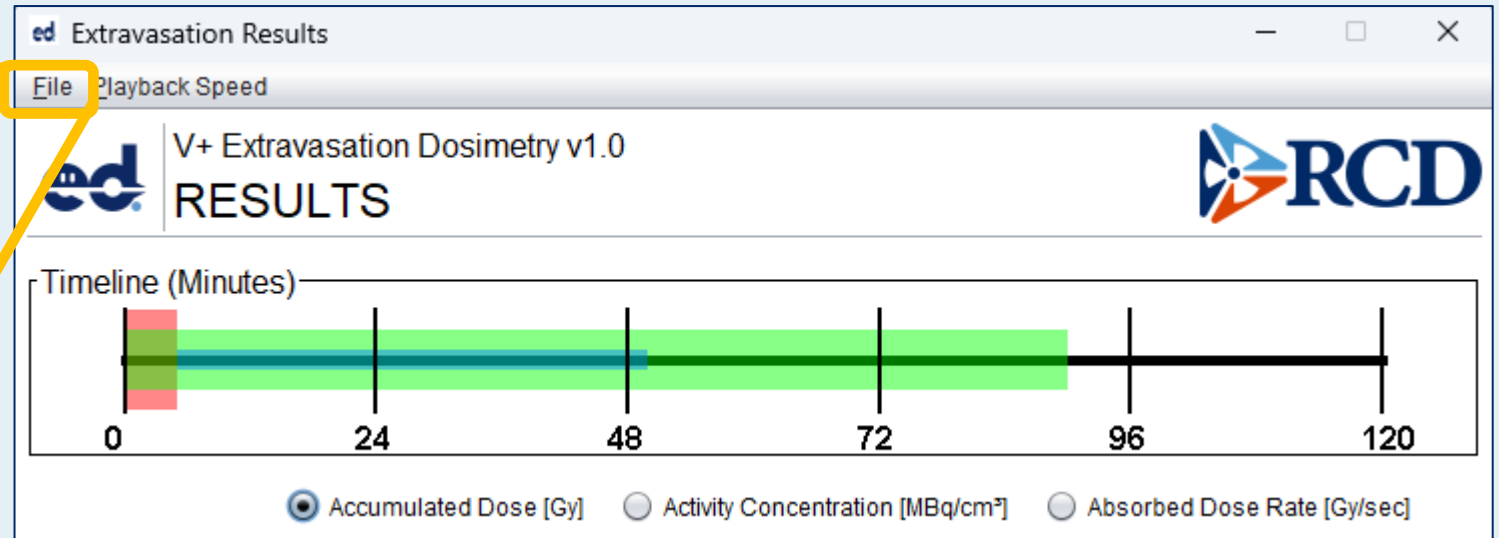
Enter Fluid Diffusivity

Enter Voxel Side Length



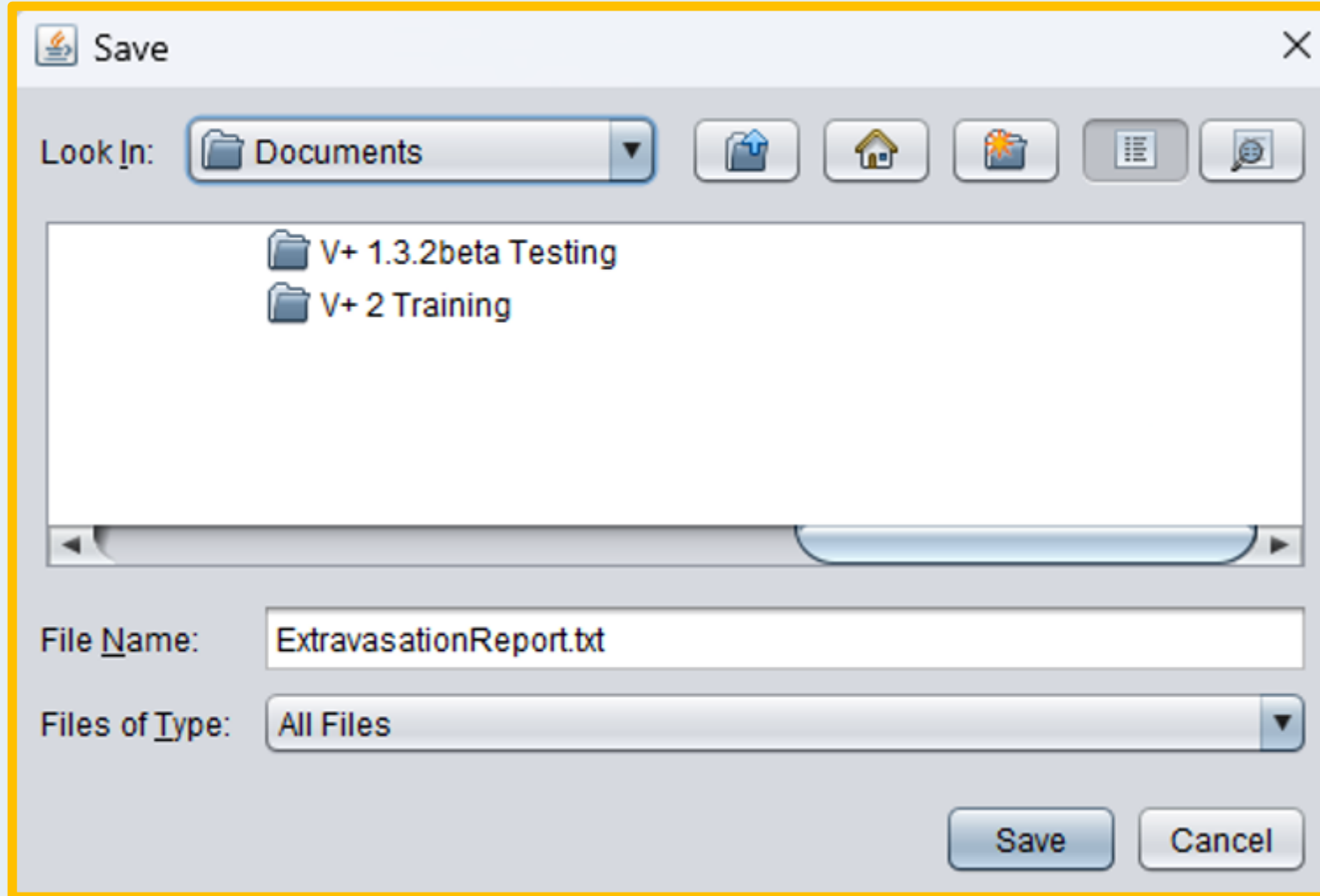
2. Text Reporting & Data Exporting

Saving Text Report



Select Save Report

Save Report before Opening



Default file name is provided

```
*****
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	cm ² /h
Fluid Diffusivity:	0.001	cm ² /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

Limb remains flat – No elevation (Lift angle = 0.0 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

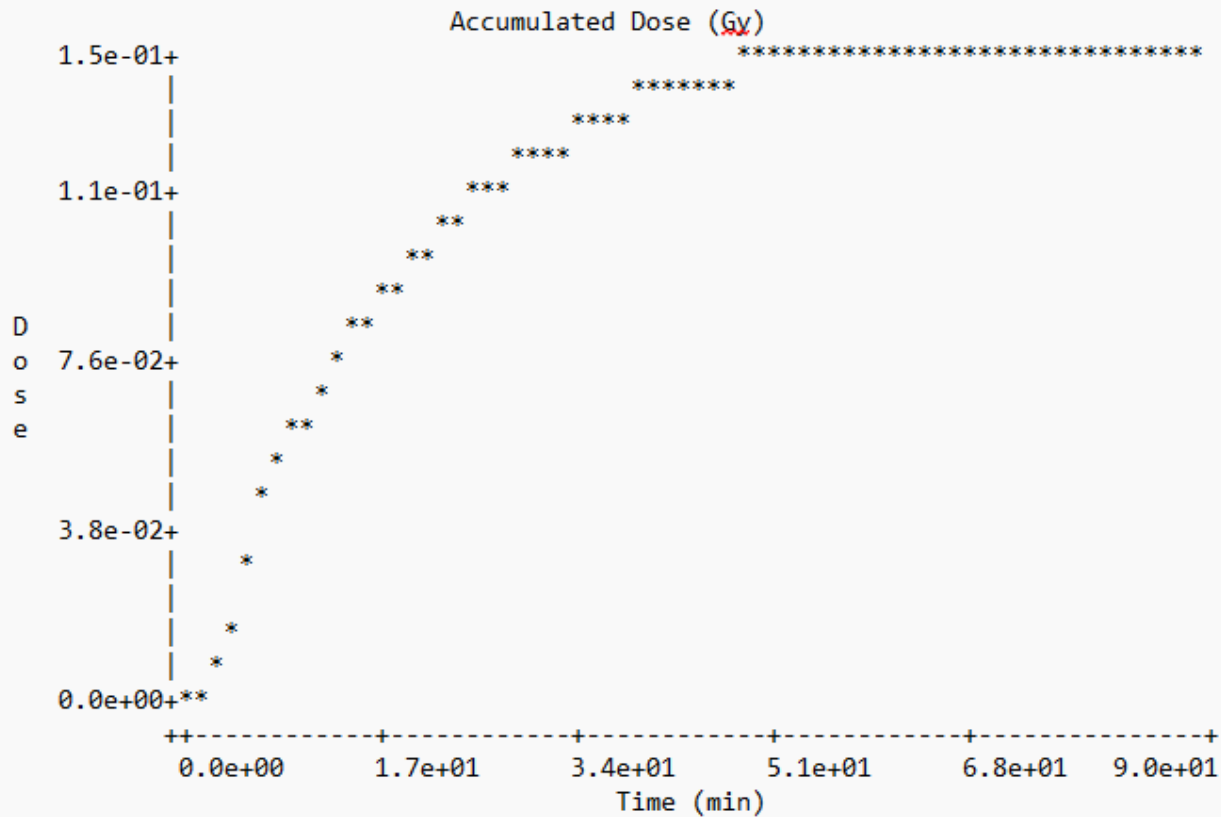
```
*****
Outputs
*****
      Max Voxel Dose:      3.84e-01      Gy
    Max Voxel Dose Rate:  8.51e-04      Gy/s
  Time to Max Voxel Dose Rate:      5.0      min
ROI Exceeding Dose Threshold:      0.0      %
      Dose to ROI:      1.52e-01      Gy
    Region Volume:      2.4      cm3
```

On-Screen Summary Results

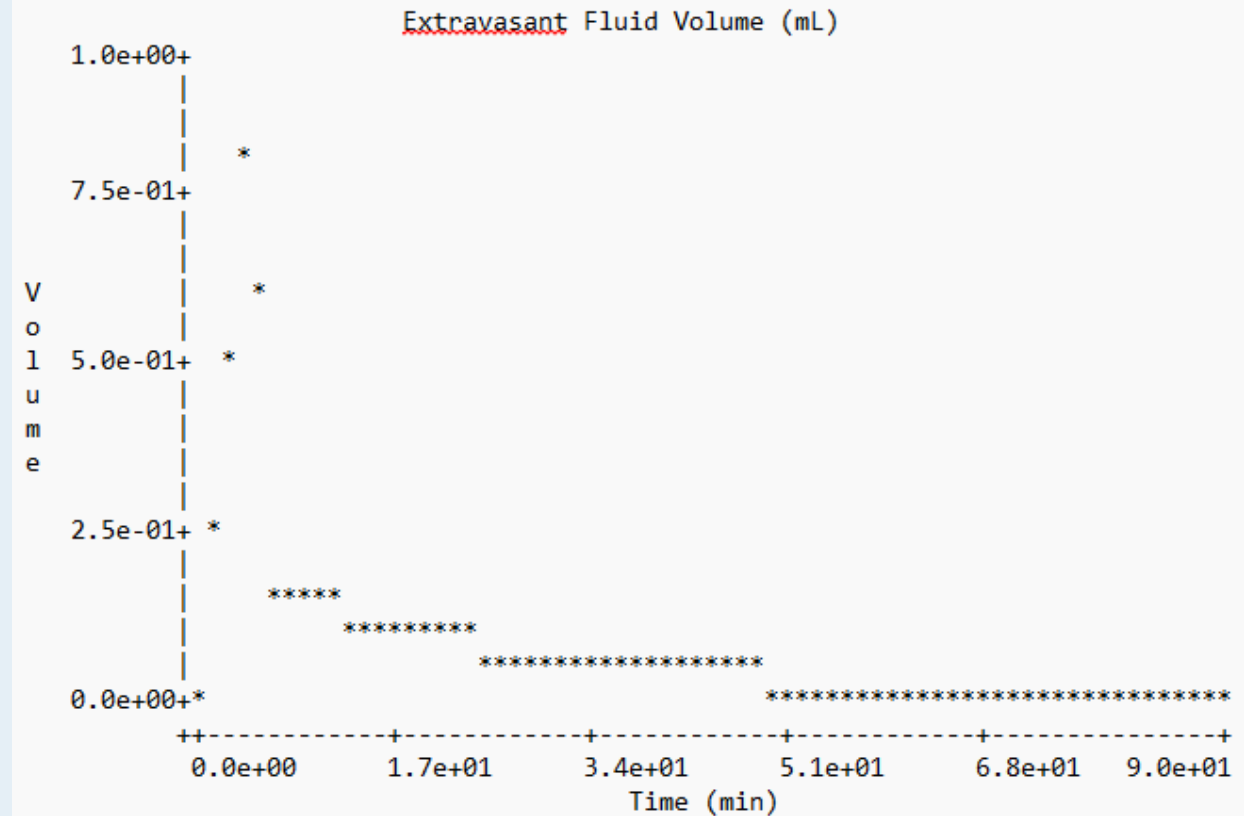
Extravasated Activity:	3.70e+02	MBq
Extravasated Volume:	1.00e+00	mL
Maximum Voxel Dose:	3.84e-01	Gy
Maximum Voxel Dose Rate:	8.51e-04	Gy/sec
Time to Maximum Voxel Dose Rate:	5.00	min
ROI Exceeding Threshold (2.0 Gy):	0.00	%
Dose to ROI:	1.52e-01	Gy

Accumulated Dose

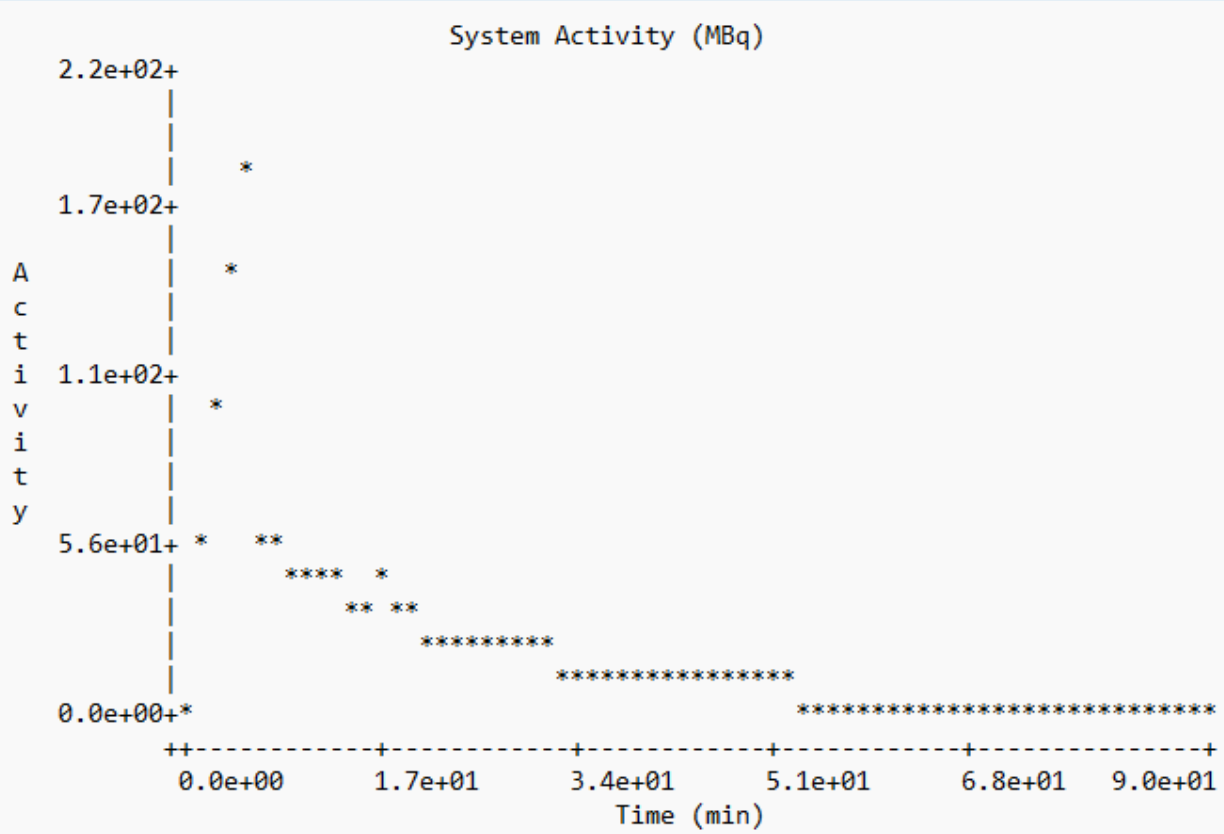
Plot(s)



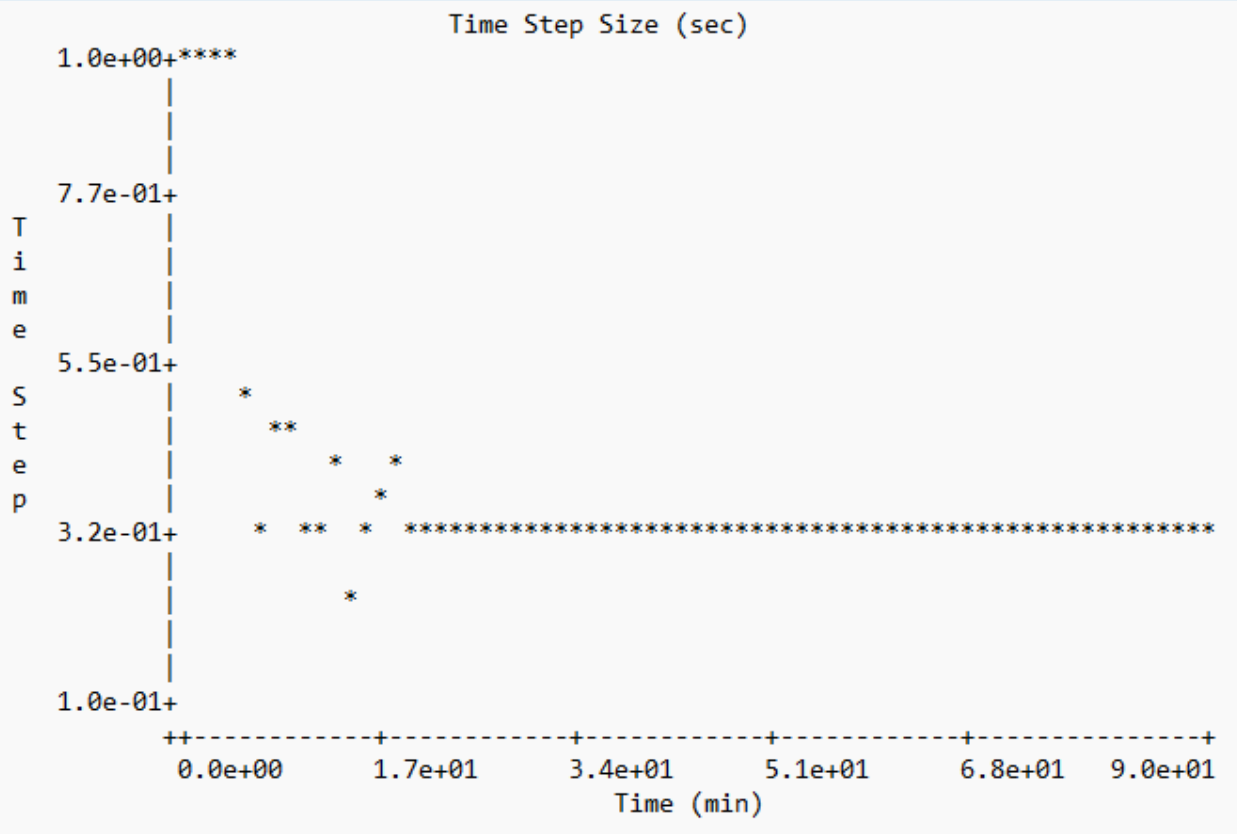
Extravasated Fluid Volume in Tissue Region



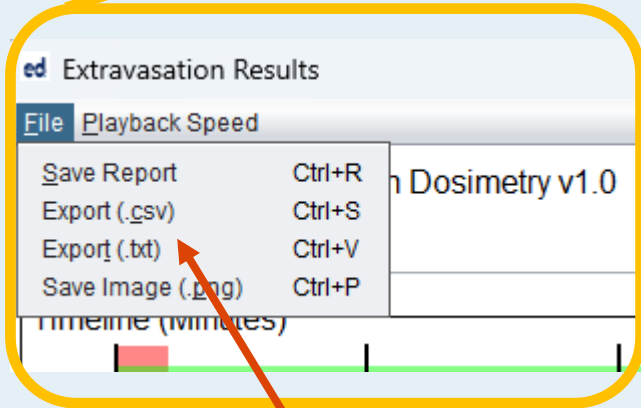
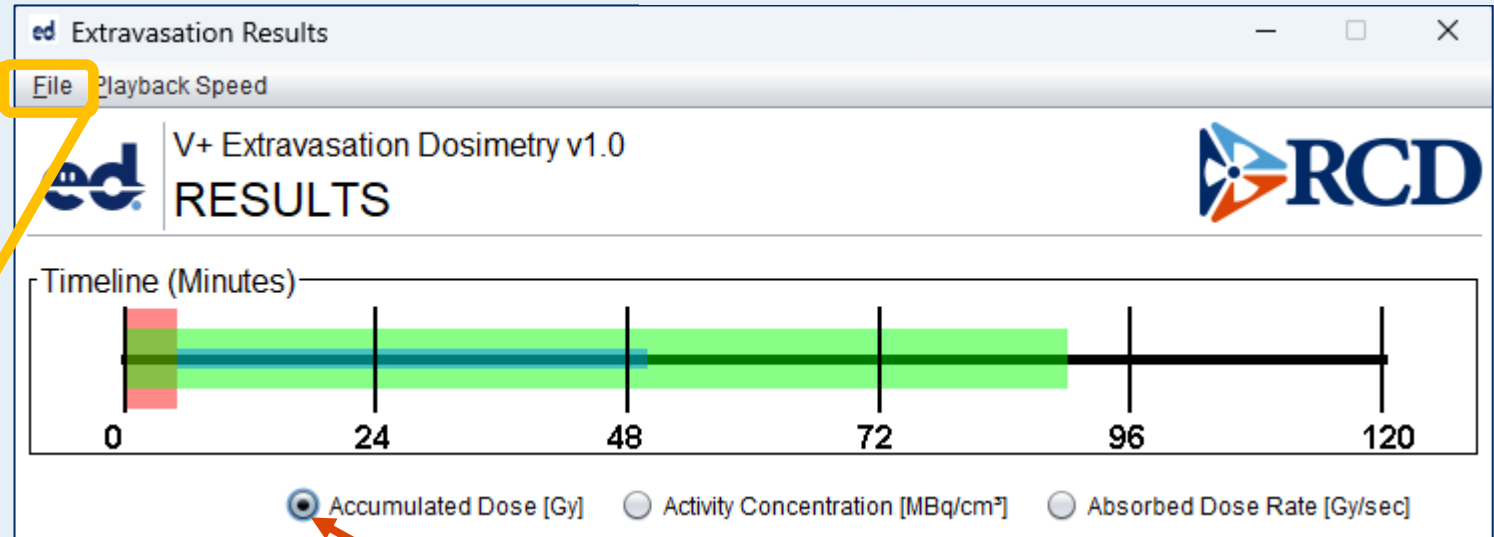
Activity in the Tissue Region of Interest



Simulation Time Step Size

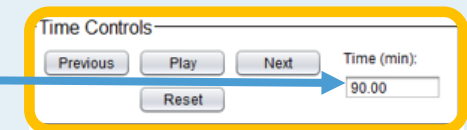


End of Report



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

ed Extravasation Dosimetry v1.0

File Mode Help

V+ Extravasation Dosimetry v1.0
MODEL INPUTS

Source and Concentration Inputs

Database: ICRP-38 ICRP-107 Concentration: 370.000 MBq/mL

Nuclide: F-18 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

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

ed 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)

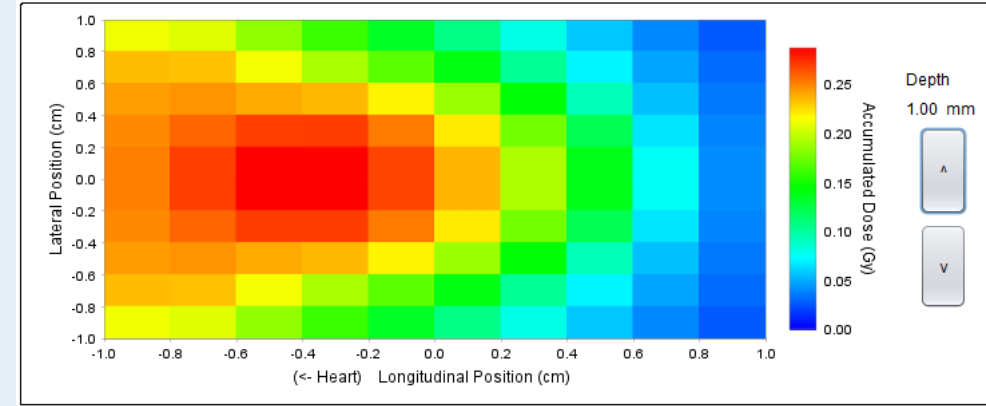
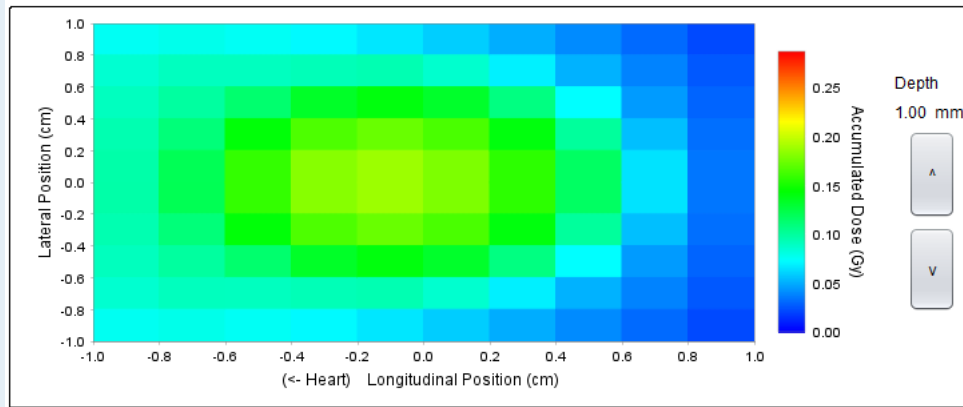
Ex. I: Accumulated doses (Gy) 15 min

Elevated end

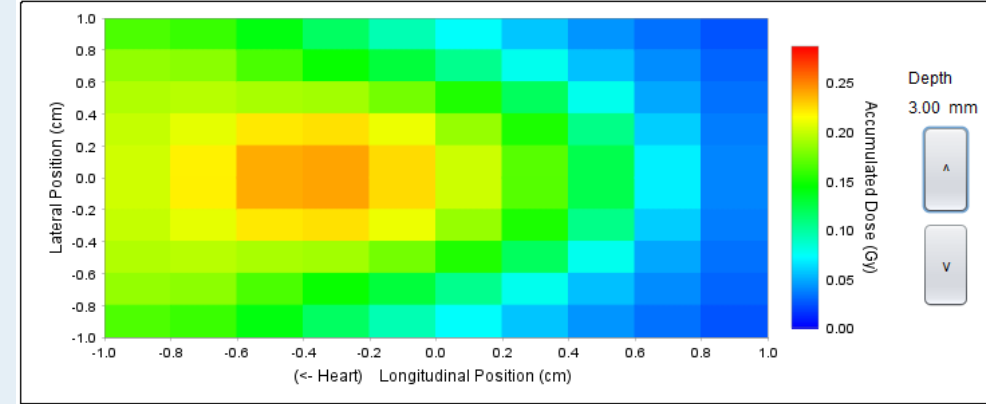
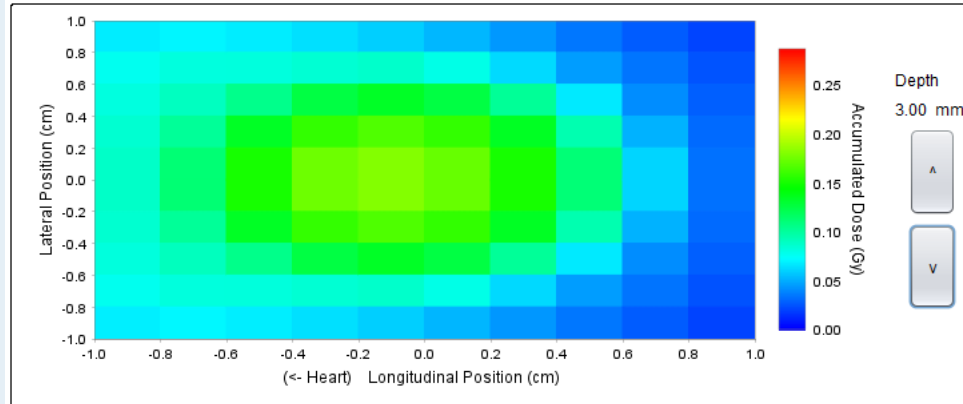
90 min

Elevated end

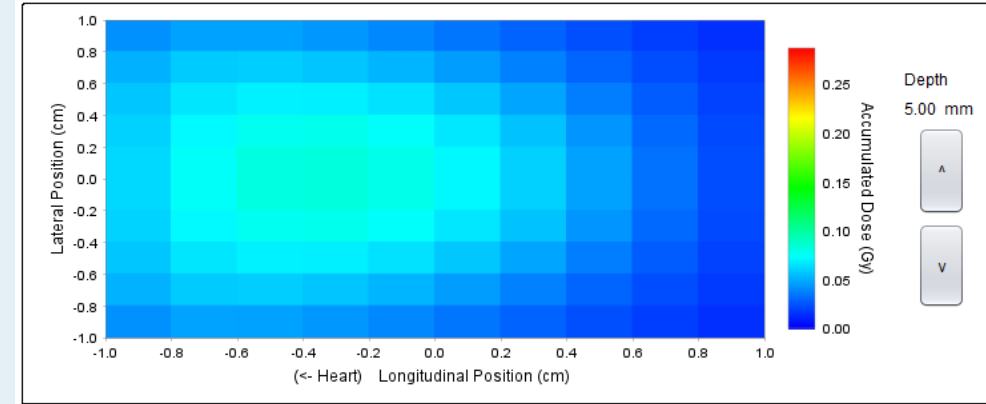
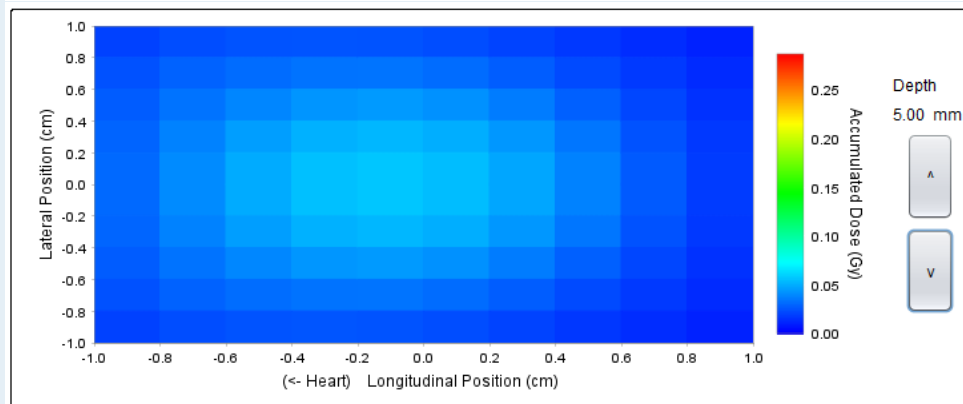
Top 2 mm



Middle 2 mm

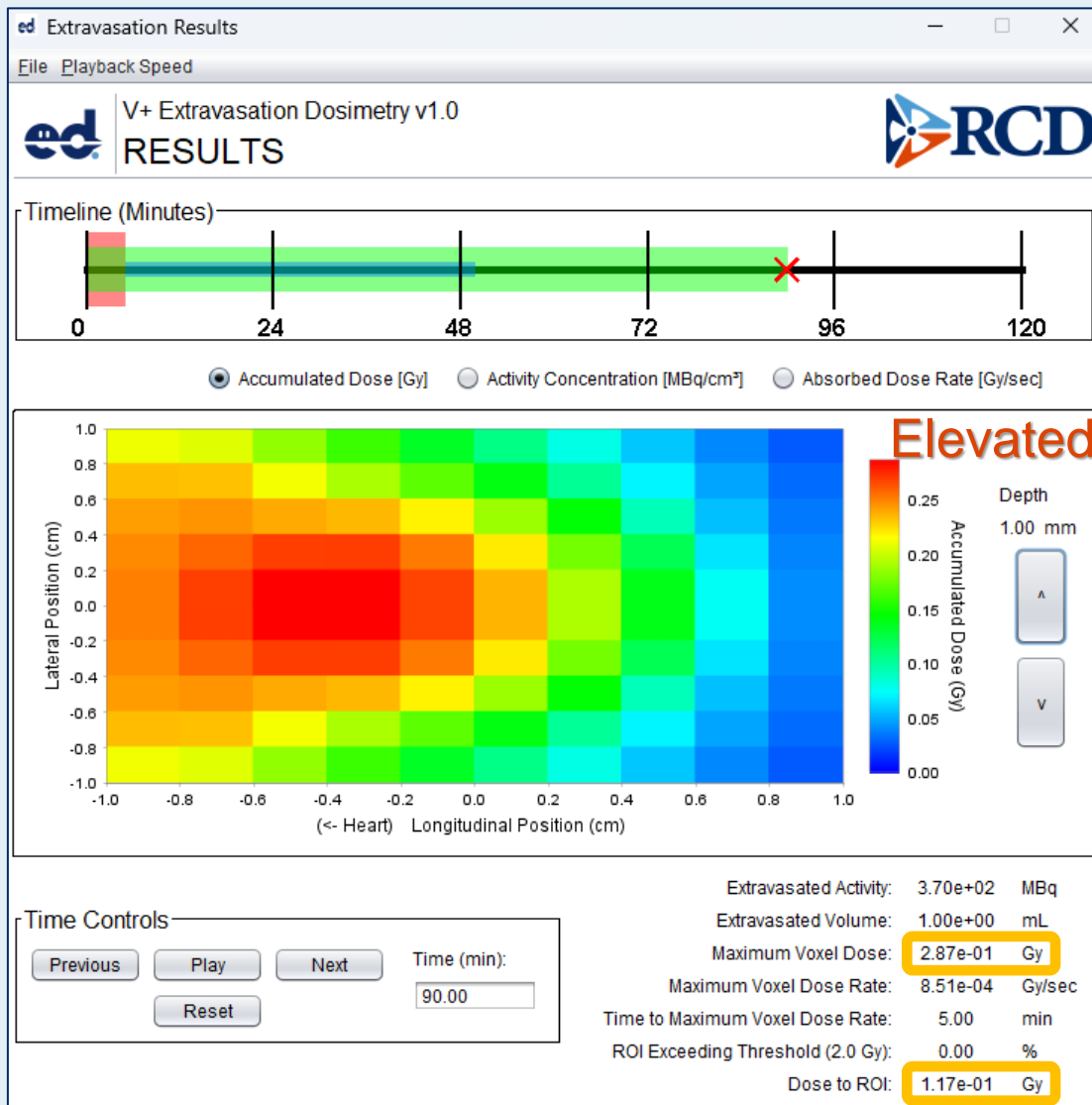


Bottom 2 mm

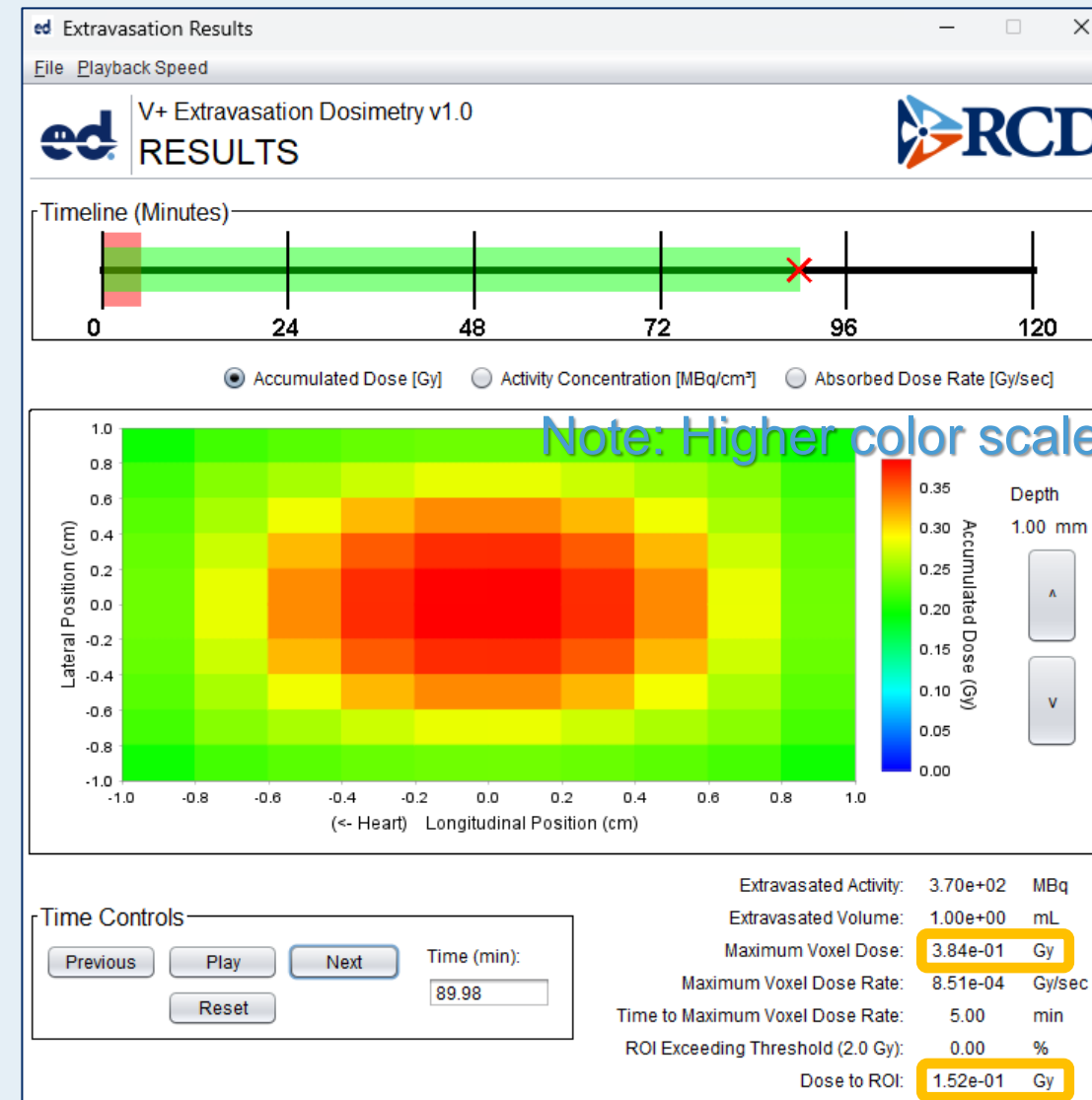


Ex. I: Influence of limb elevation on accumulated doses (Gy)

Elevated limb



Limb remains flat – No elevation



Example II: Basic & Advanced comparison

Example II: Switching **Basic** → **Advanced** calculation yields same results

ed 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 Heterogeneous
 Number of Layers: 1
 Layer 1 Effective Tissue Thickness: 1.000 cm

Transport Inputs
 Dose Notification Threshold: 1.000 Gy
 Region Width: 10.000 cm
 Region Length: 20.000 cm

Diagram

Not to scale

Basic

Timeline Calculate Results

ed 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 Heterogeneous
 Number of Layers: 1
 Layer 1 Effective Tissue Thickness: 1.000 mm
 Lateral Transmissivity: 3.000 cm²/h

Transport Inputs
 Dose Notification Threshold: 1.000 Gy
 Region Width: 10.000 cm
 Region Length: 20.000 cm
 Vertical Transmissivity: 1.000 cm²/h
 Fluid Diffusivity: 0.100 cm²/h
 Voxel Side Length: 1.000 cm

Diagram

Not to scale

Advanced

Timeline Calculate Results

ed Extravasation Results

RESULTS **Basic**

Timeline (Hours)

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

Accumulated Dose (Gy)

Lateral Position (cm) Longitudinal Position (cm) (<- Heart)

Time Controls
 Previous Play Next Time (min): 479.90
 Reset

Extravasated Activity: 1.85e+02 MBq
 Extravasated Volume: 5.00e+00 mL
 Maximum Voxel Dose: 3.58e-01 Gy
 Maximum Voxel Dose Rate: 8.31e-04 Gy/sec
 Time to Maximum Voxel Dose Rate: 10.00 min
 ROI Exceeding Threshold (1.0 Gy): 0.00 %
 Dose to ROI: 3.02e-02 Gy

ed Extravasation Results

RESULTS **Advanced**

Timeline (Hours)

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

Accumulated Dose (Gy)

Lateral Position (cm) Longitudinal Position (cm) (<- Heart)

Time Controls
 Previous Play Next Time (min): 479.90
 Reset

Extravasated Activity: 1.85e+02 MBq
 Extravasated Volume: 5.00e+00 mL
 Maximum Voxel Dose: 3.58e-01 Gy
 Maximum Voxel Dose Rate: 8.31e-04 Gy/sec
 Time to Maximum Voxel Dose Rate: 10.00 min
 ROI Exceeding Threshold (1.0 Gy): 0.00 %
 Dose to ROI: 3.02e-02 Gy

Example III: Trapped fluid (special case)

Example III input: Trapped fluid (special case)

ed Extravasation Dosimetry v1.0

File Mode Help

V+ Extravasation Dosimetry v1.0

MODEL INPUTS

Source and Concentration Inputs

Database: ICRP-38 ICRP-107 Concentration: 37.000 MBq/mL

Nuclide: F-18 Flow Rate: 0.500 mL/min

Layer Inputs

Tissue Model: Homogeneous Heterogeneous

Number of Layers: 1

Layer 1

Effective Tissue Thickness: 8.000 mm

Lateral Transmissivity: 0.010 cm²/h

Transport Inputs

Dose Notification Threshold: 1.000 Gy

Region Width: 4.800 cm

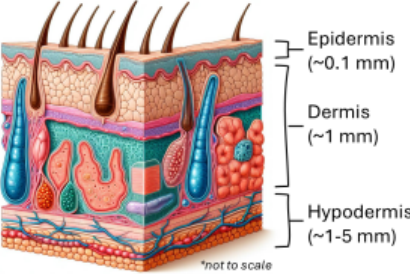
Region Length: 8.000 cm

Vertical Transmissivity: 0.010 cm²/h


Fluid Diffusivity: 0.010 cm²/h

Voxel Side Length: 8.000 mm

Diagram



Timeline Calculate Results

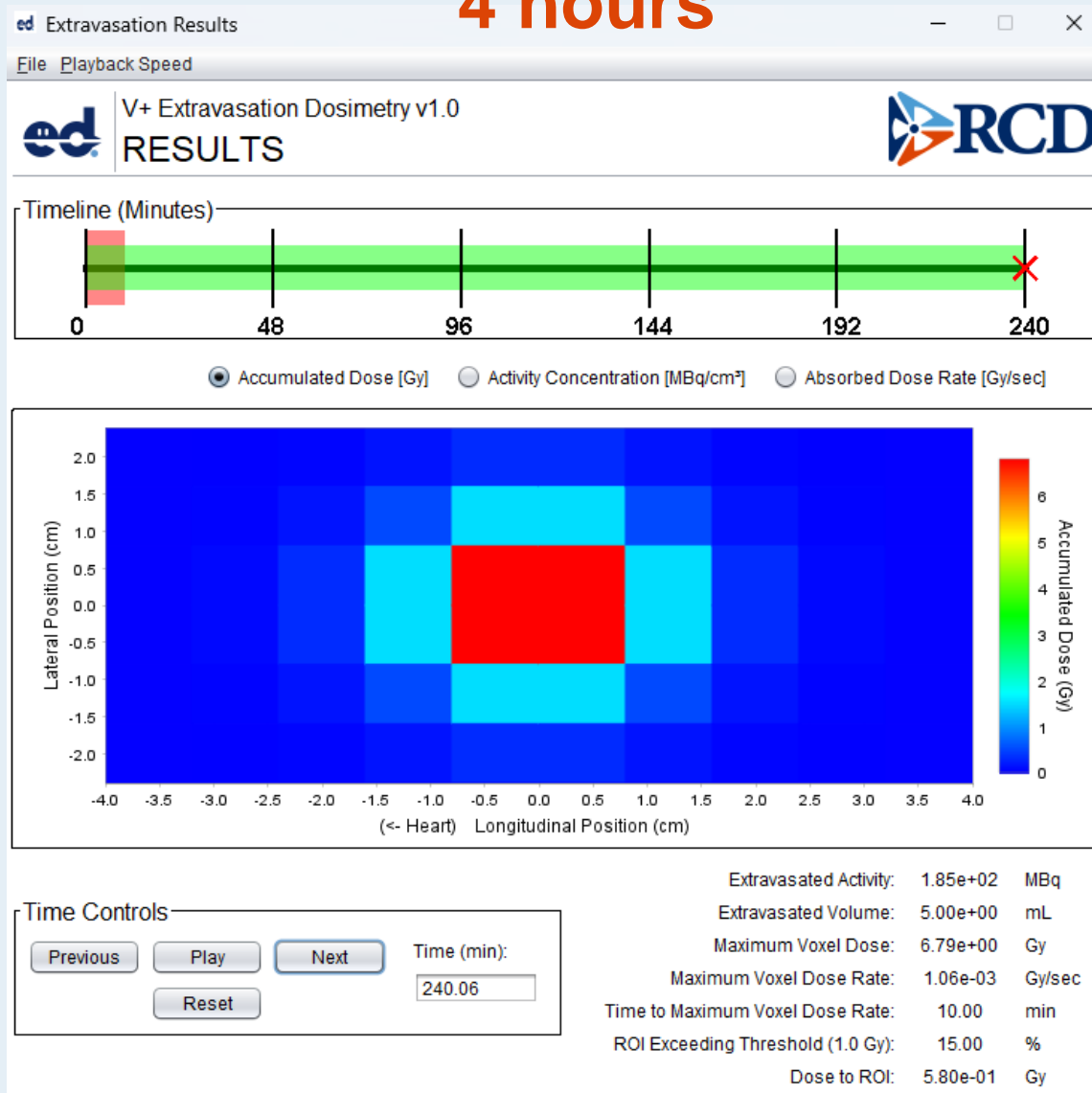


Small values for transmissivity & diffusivity

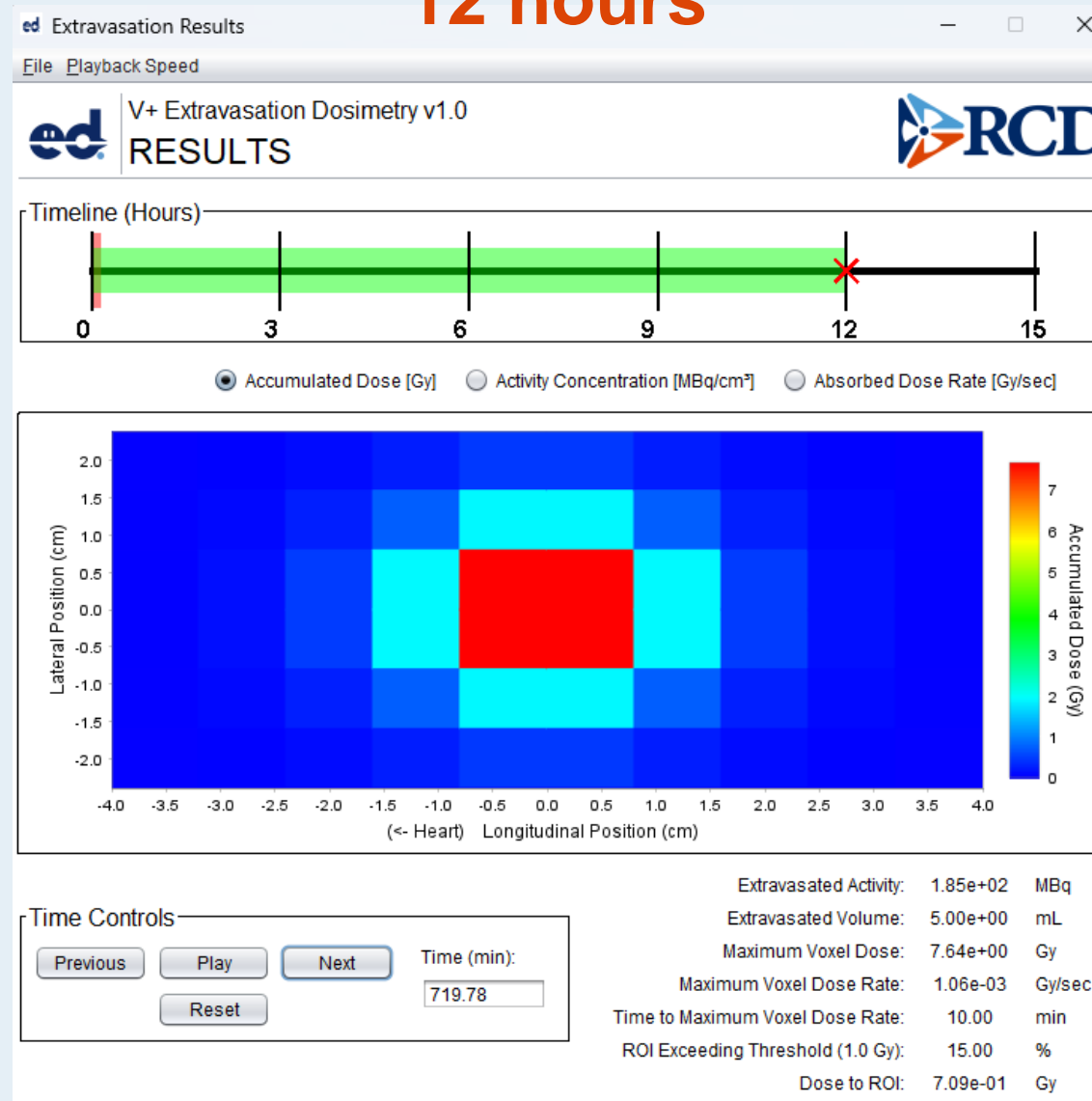
Compare results for different analysis times
(next slide)

Example III results for different analysis times

4 hours



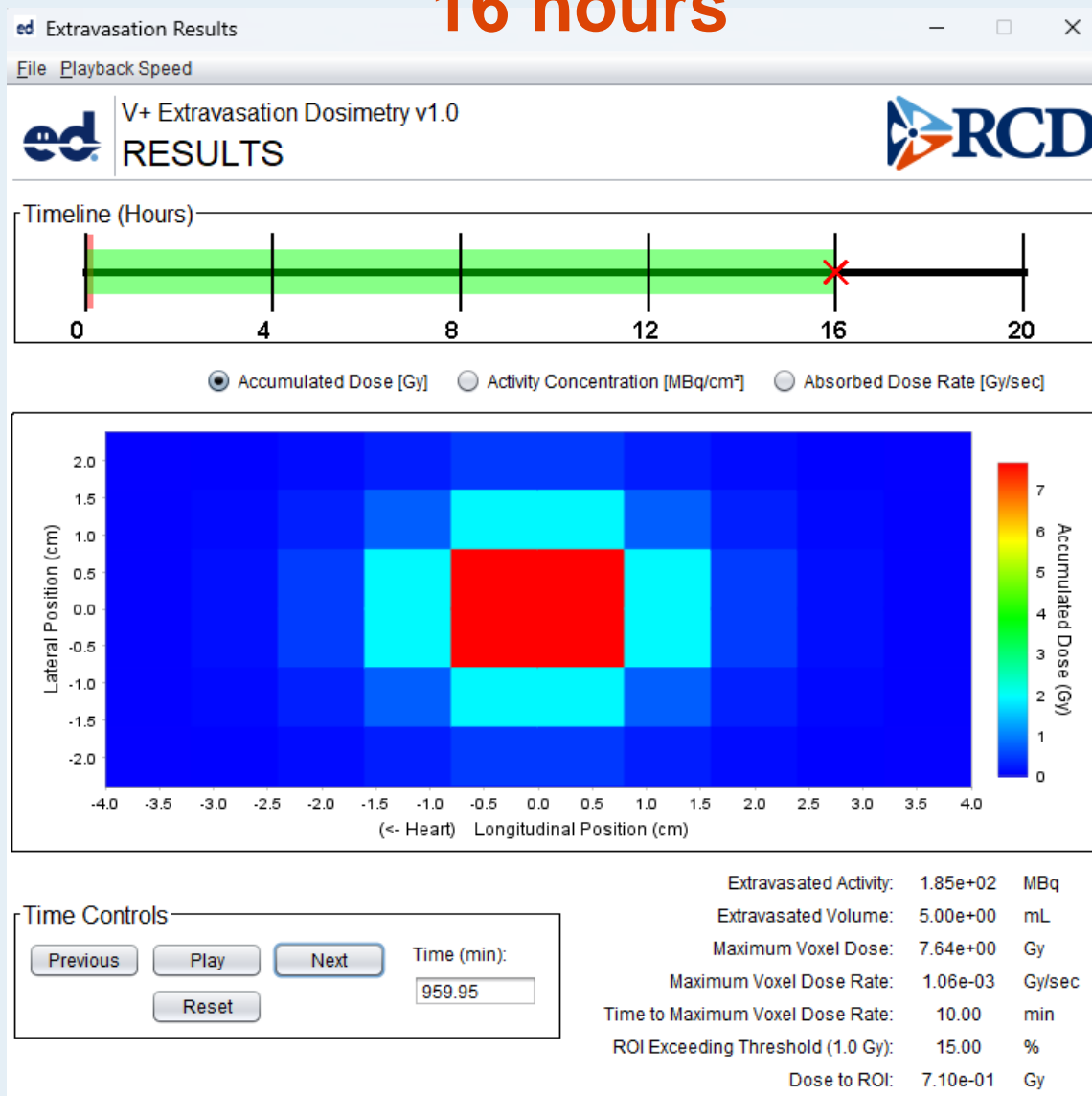
12 hours



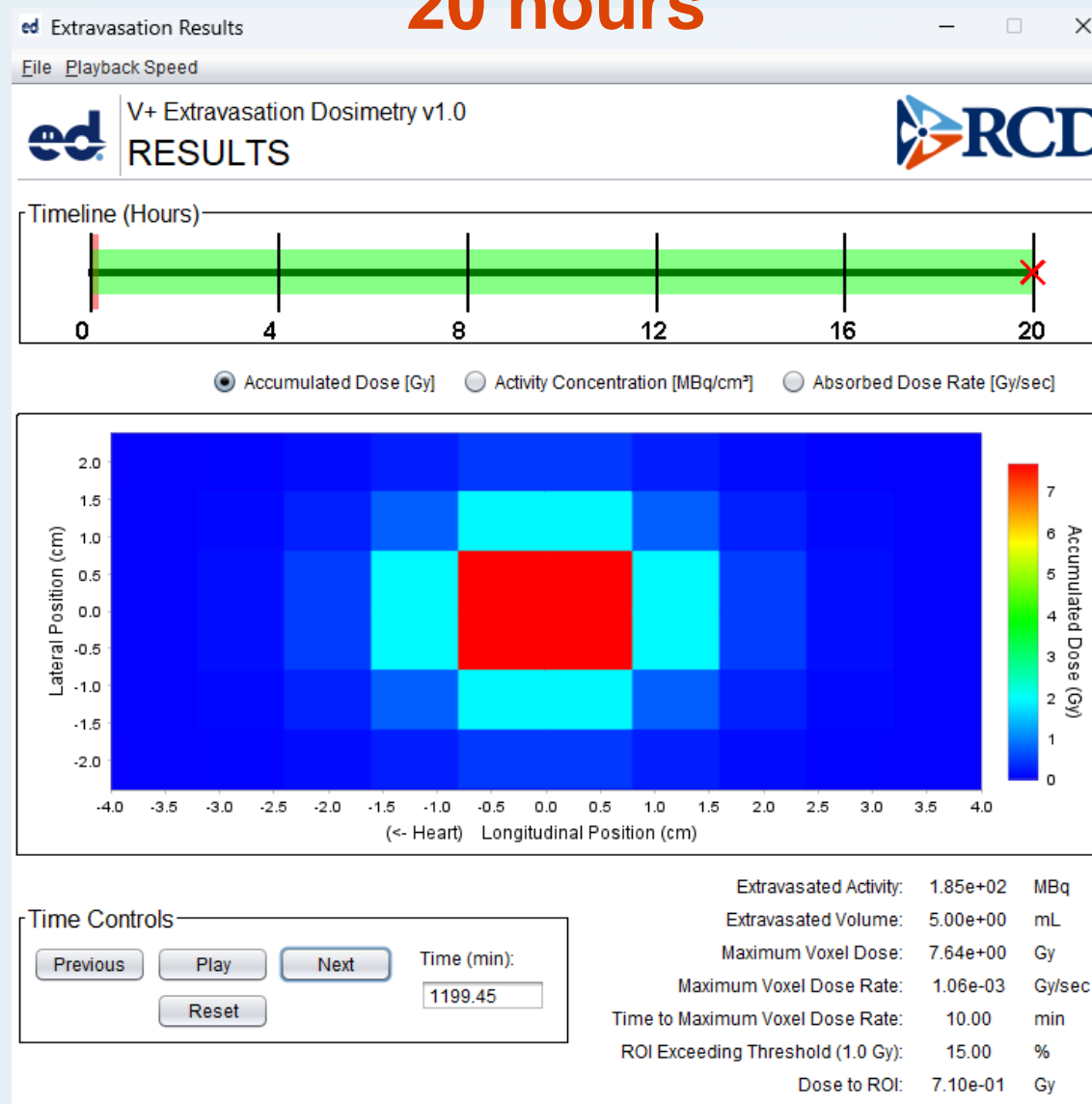
Example III results for different analysis times (cont'd)



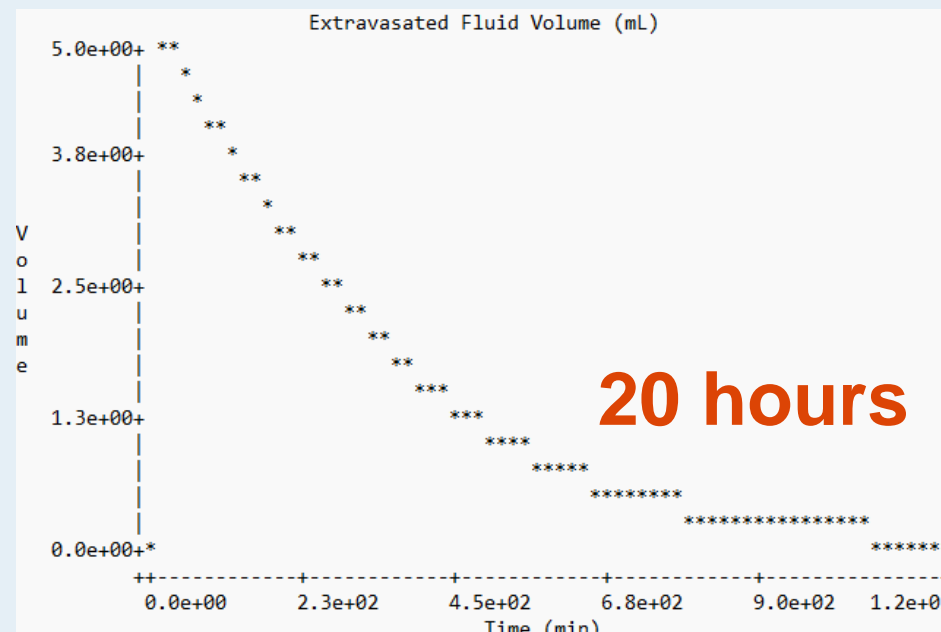
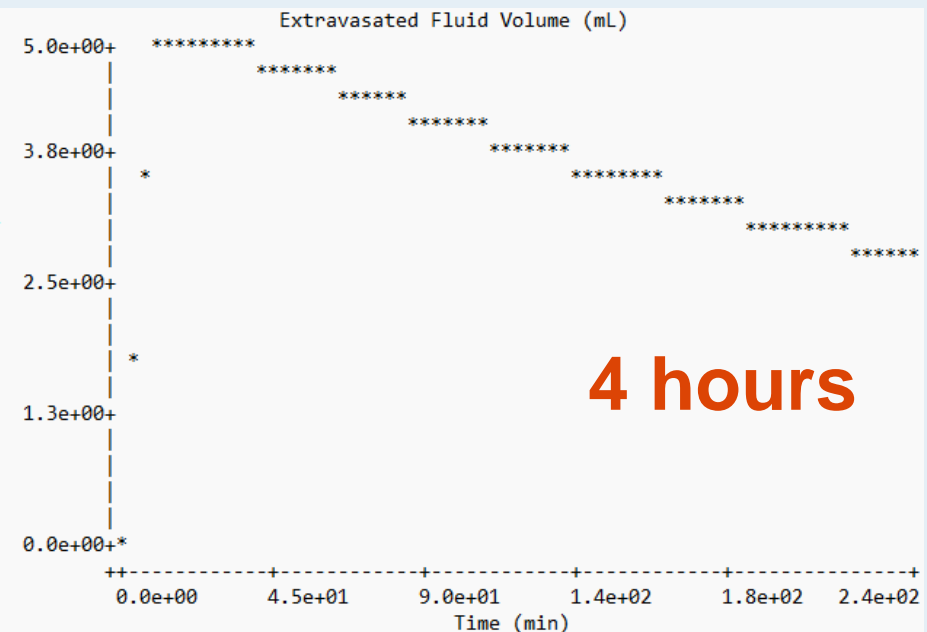
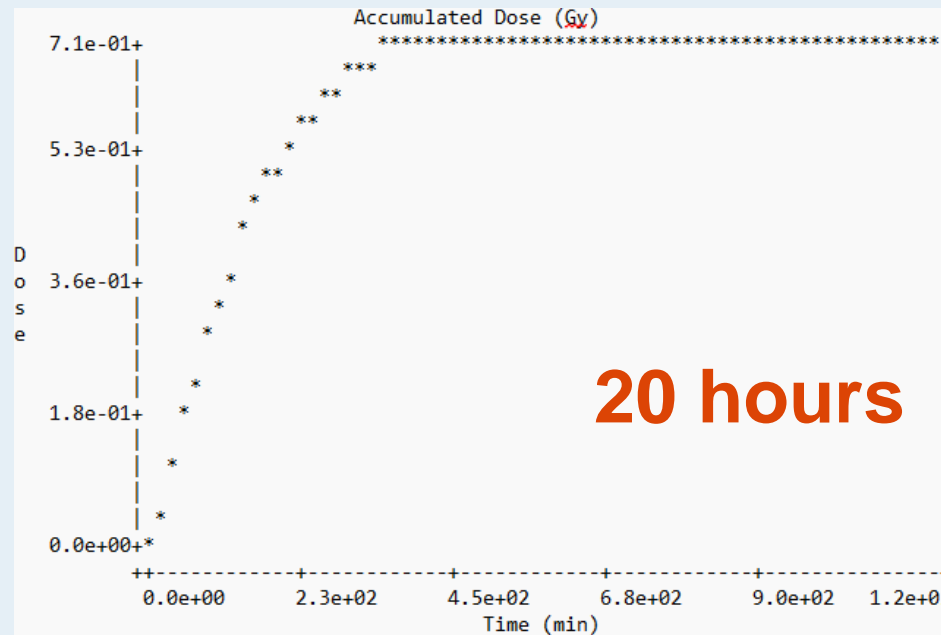
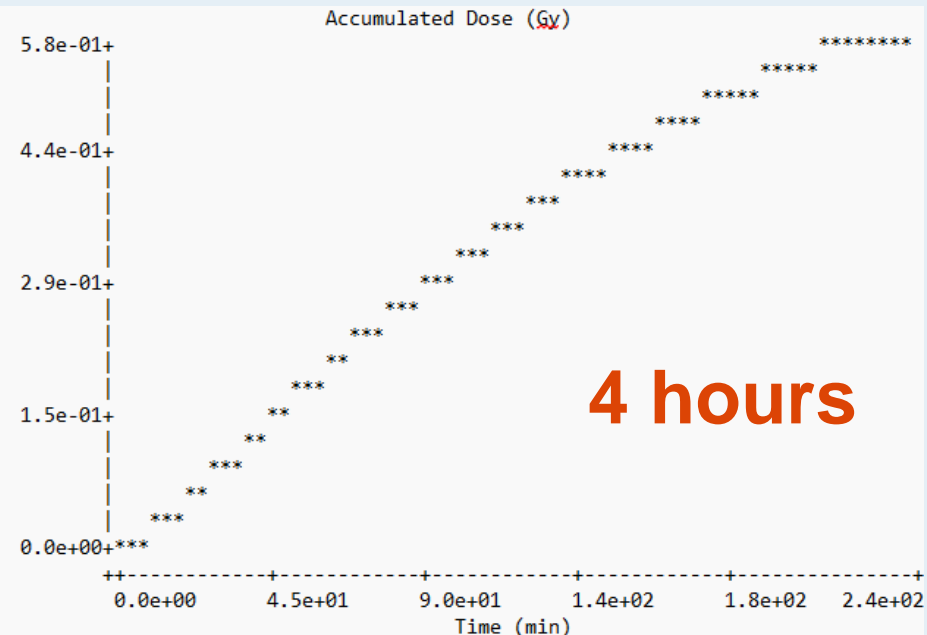
16 hours



20 hours



Example III report plots



Example IV: Parameter memory

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

Example VI builds on Example III (Advanced 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 Heterogeneous
 Number of Layers: **1**
 Layer 1
 Effective Tissue Thickness: **8.000** mm
 Lateral Transmissivity: **0.010** cm²/h

Transport Inputs

Dose Notification Threshold: **1.000** Gy
 Region Width: **4.800** cm
 Region Length: **8.000** cm
 Vertical Transmissivity: **0.010** cm²/h
 Fluid Diffusivity: **0.010** cm²/h
 Voxel Side Length: **8.000** mm

Extravasation Results

File Playback Speed

V+ Extravasation Dosimetry v1.0
RESULTS

Timeline (Hours)

Accumulated Dose [Gy] Activity Concentration [MBq/cm²] Absorbed Dose Rate [Gy/sec]

Lateral Position (cm) vs. Longitudinal Position (cm) (\leftarrow Heart)

Time Controls

Previous Play Next Time (min): **719.78**
 Reset

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

Extravasation Timeline

V+ Extravasation Dosimetry v1.0
EVENT INPUTS

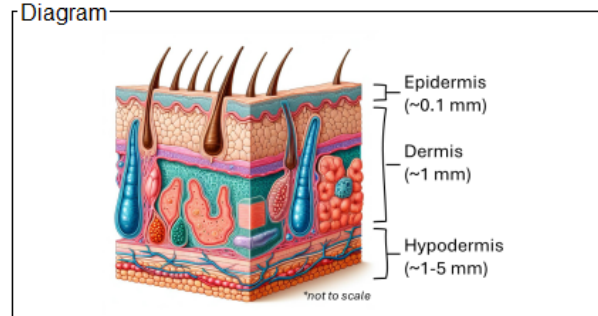
#	Event	Day	Start Time	End Time	Duration (hr)
1	Extravasation	1	12:00AM	12:10AM	0.17
2	Analysis Period	1	12:00PM	12:00PM	12.00

Add/Delete Events
 Add Event Delete Selected Event

Edit Selected Event (#2)

Type: **Analysis Period**
 Day: **1**
 Start Time: **12:00** AM
 End Time: **12:00** PM
 Duration: **12.00** Hours
 Elevation: **0.0** Degrees

Timeline (Hours)



Timeline Calculate Results



Parameter Memory Demonstrated

Advanced Calculation switched to **Basic Calculation**



ed Extravasation Dosimetry v1.0

File Mode Help

V+ Extravasation Dosimetry v1.0
MODEL INPUTS

Source and Concentration Inputs

Database: ICRP-38 ICRP-107

Nuclide:

Concentration: MBq/mL

Flow Rate: mL/min

Layer Inputs

Tissue Model: Homogeneous

Number of Layers:

Layer 1

Effective Tissue Thickness: mm

Transport Inputs

Dose Notification Threshold: Gy

Region Width: cm

Region Length: cm

Diagram

Timeline Calculate Results

Basic Calculation after Advanced Calculation includes **Parameter Memory**

ed 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]

Lateral Position (cm)

Longitudinal Position (cm) (<- Heart)

Time Controls

Previous Play Next Time (min):

Reset

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)



ed Extravasation Dosimetry v1.0

File Mode Help

V+ Extravasation Dosimetry v1.0
MODEL INPUTS

Source and Concentration Inputs

Database: ICRP-38 ICRP-107

Nuclide:

Concentration: MBq/mL

Flow Rate: mL/min

Layer Inputs

Tissue Model: Homogeneous

Number of Layers:

Layer 1

Effective Tissue Thickness: mm

Transport Inputs

Dose Notification Threshold: Gy

Region Width: cm

Region Length: cm

Diagram

Timeline Calculate Results

**New Basic Calculation after Program Restart implies...
No Parameter Memory**

ed Extravasation Results

File Playback Speed

V+ Extravasation Dosimetry v1.0
RESULTS

Timeline (Hours)

Accumulated Dose [Gy] Activity Concentration [MBq/cm²] Absorbed Dose Rate [Gy/sec]

Time Controls

Previous Play Next Time (min):

Reset

Extravasated Activity: 1.85e+02 MBq
Extravasated Volume: 5.00e+00 mL
Maximum Voxel Dose: 3.47e-01 Gy
Maximum Voxel Dose Rate: 8.44e-04 Gy/sec
Time to Maximum Voxel Dose Rate: 8.27 min
ROI Exceeding Threshold (1.0 Gy): 0.00 %
Dose to ROI: 5.33e-02 Gy



Parameter Memory Demonstrated (cont'd)



Basic Calculation after Advanced Calculation

New Basic Calculation after Program Restart

Source and Concentration Inputs
Database: ICRP-38 ICRP-107
Nuclide:
Concentration:

Layer Inputs
Tissue Model: Homogeneous
Number of Layers:
Layer 1
Effective Tissue Thickness:

Source and Concentration Inputs
Database: ICRP-38 ICRP-107
Concentration:
Flow Rate:

Transport Inputs
Dose Notification Threshold:
Region Width:
Region Length:

Basic inputs appear identical.

#	Event	Day	Start Time	End Time	Duration (hr)
1	Extravasation	1	12:00AM	12:10AM	0.17
2	Analysis Period	1	12:00AM	12:00PM	12.00

#	Event	Day	Start Time	End Time	Duration (hr)
1	Extravasation	1	12:00AM	12:10AM	0.17
2	Analysis Period	1	12:00AM	12:00PM	12.00

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

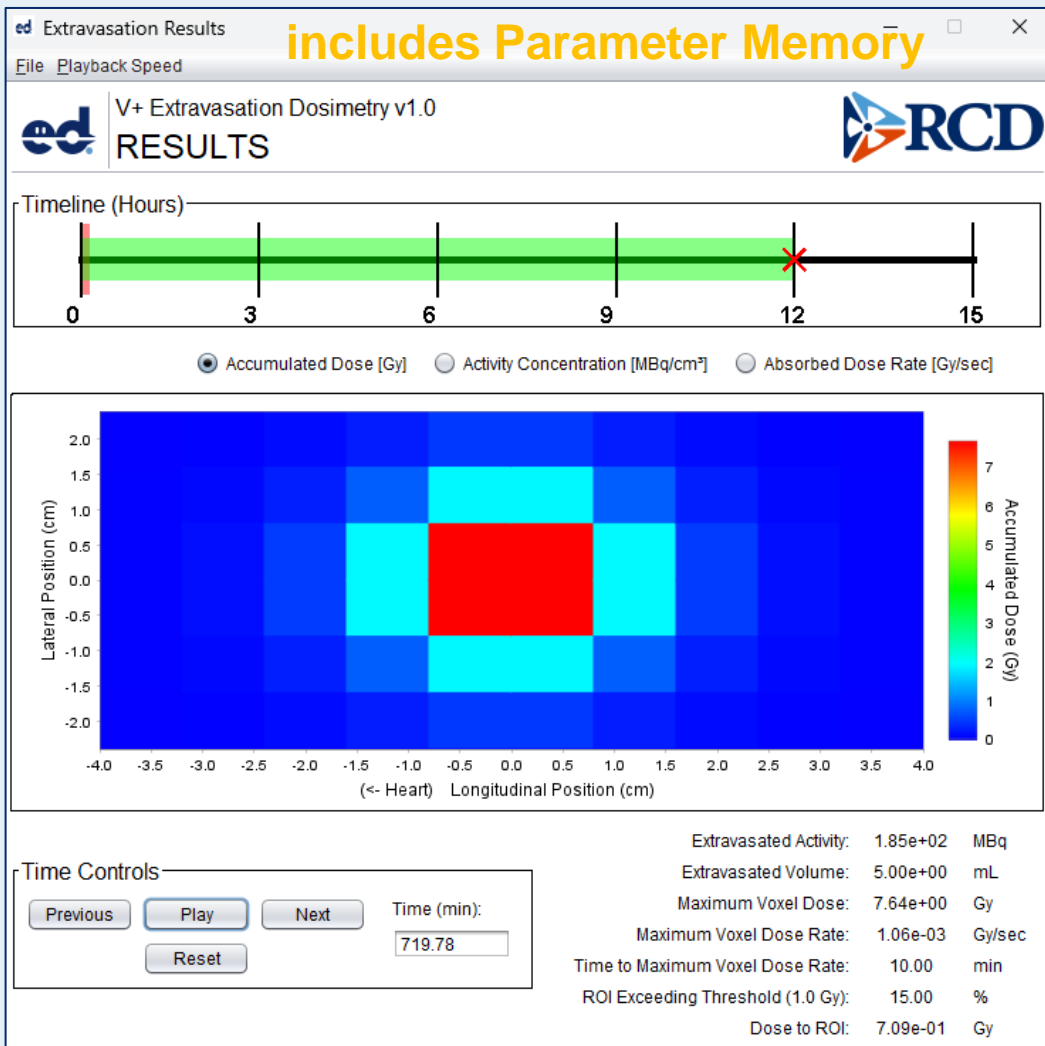
No parameter memory implies Basic calculation begins with all defaults.



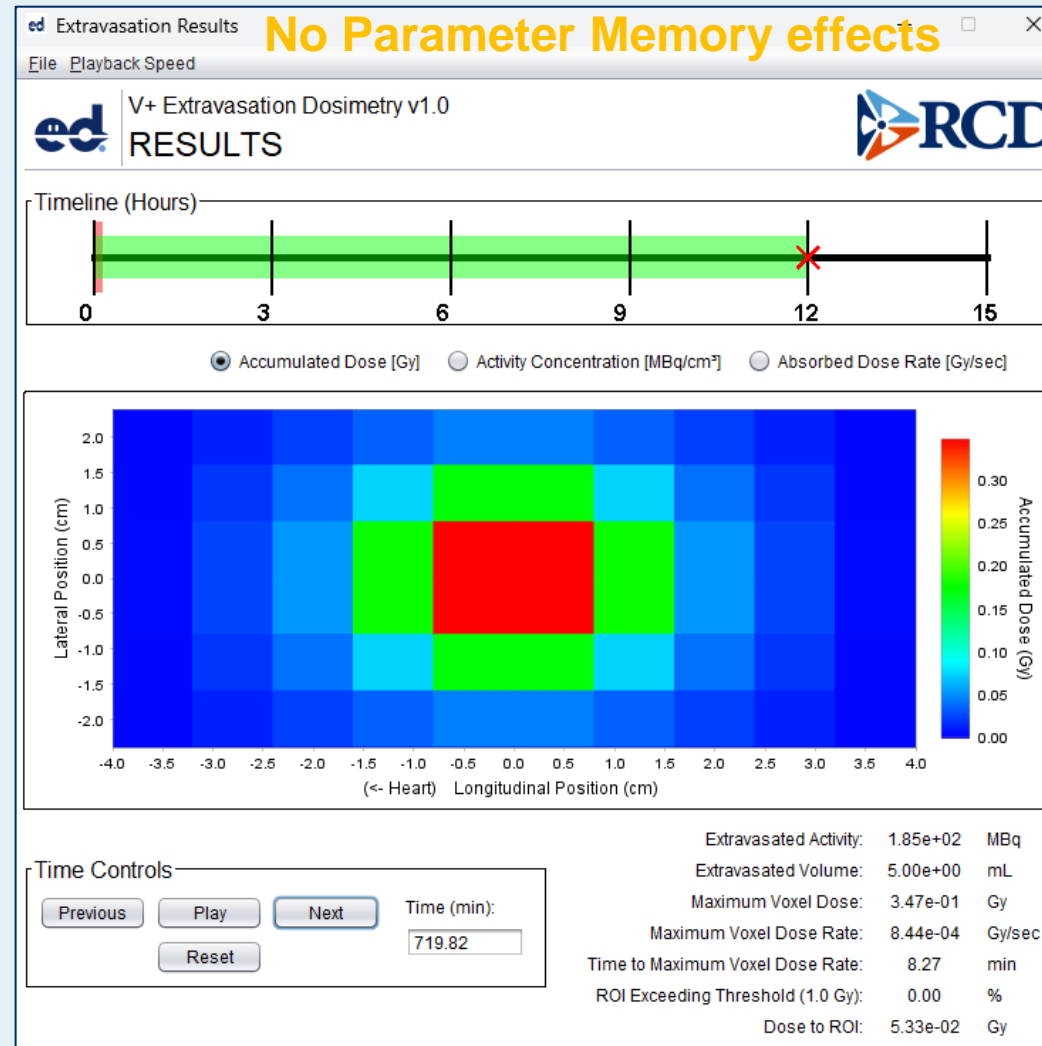
Parameter Memory Can Influence Basic Calculation Results



Basic Calculation after Advanced Calculation



New Basic Calculation after Program Restart



ExtravDose Report Shows Parameter Values in Memory



Basic Calculation after Advanced Calculation

New Basic Calculation after Program Restart

 User Inputs

includes Parameter Memory

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	cm ² /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	cm ² /h	←
Fluid Diffusivity:	0.01	cm ² /h	←
Cubic Voxel Side Length:	8.0	mm	

 User Inputs

No Parameter Memory effects

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	cm ² /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	cm ² /h	←
Fluid Diffusivity:	0.1	cm ² /h	←
Cubic Voxel Side Length:	8.0	mm	



Example V: Trapped fluid with different radionuclides

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

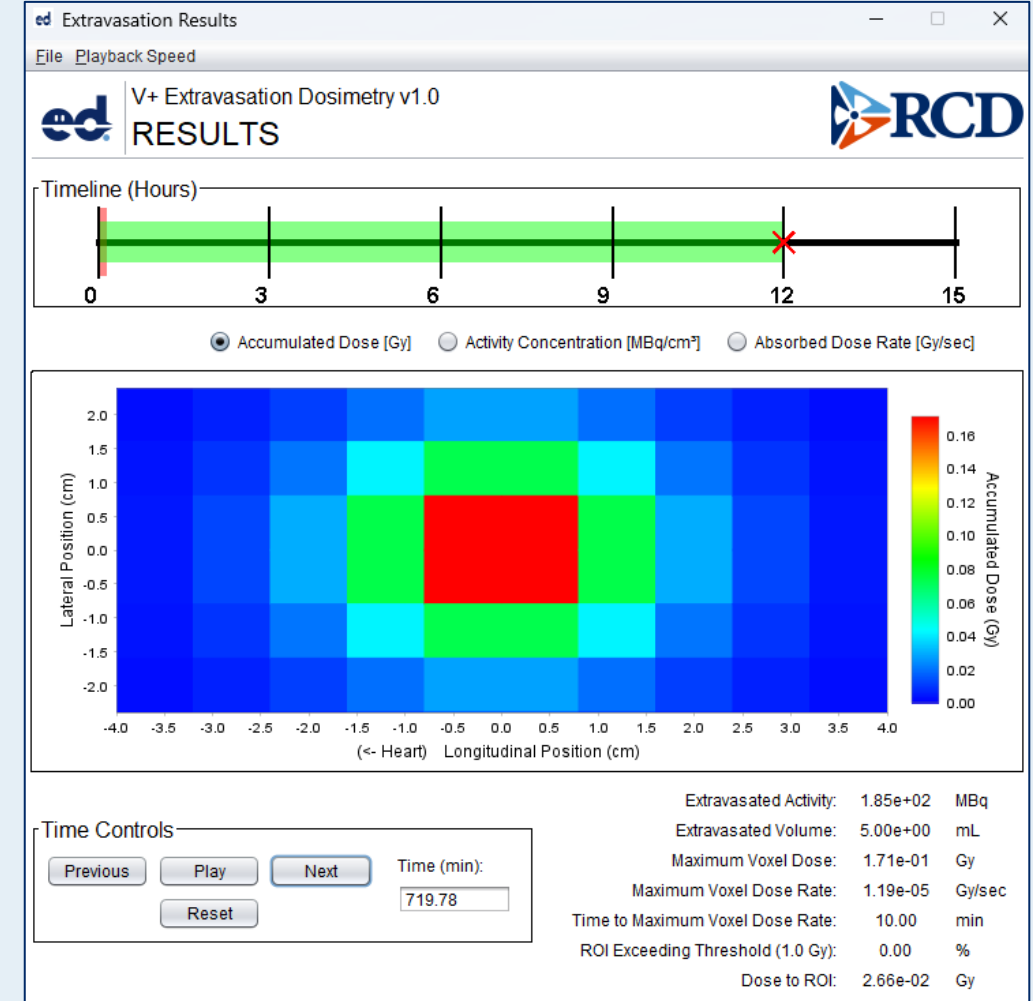
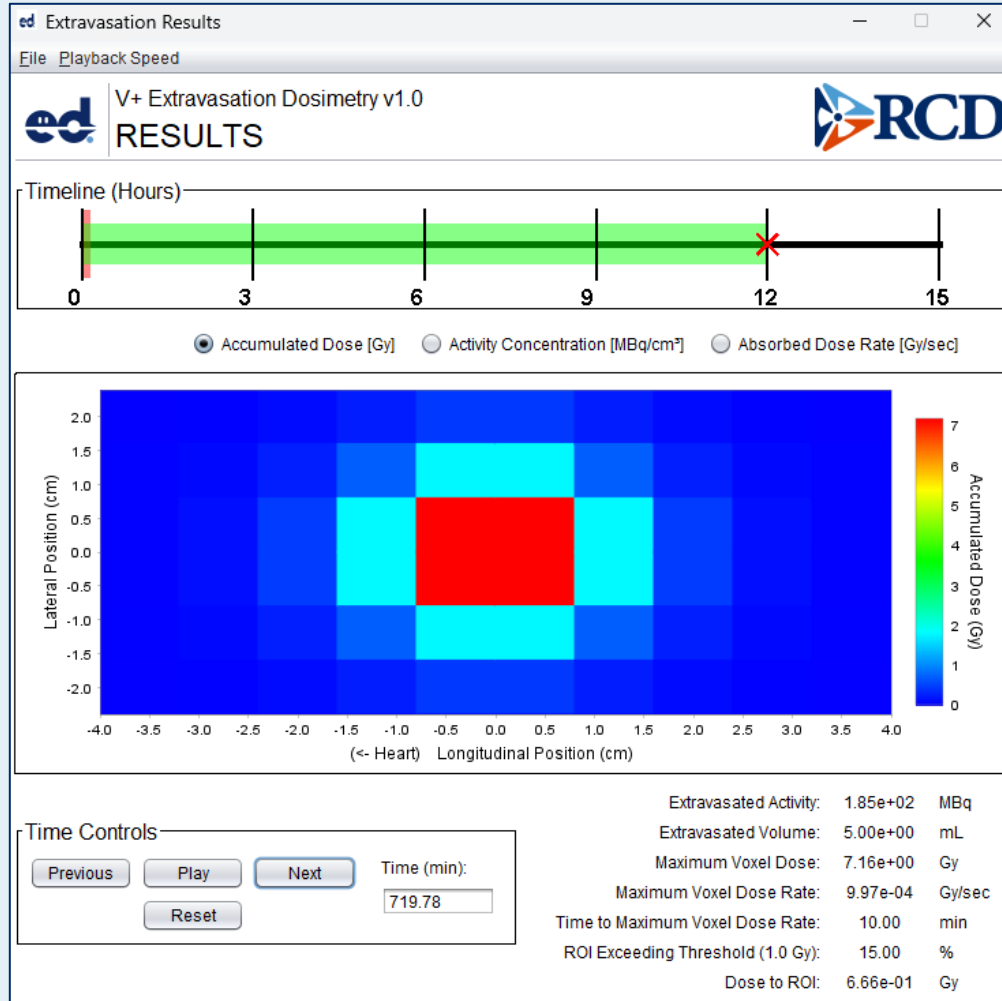
5-mCi Activity in Trapped Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.01 cm²/h



¹⁸F 0.67 Gy to ROI

^{99m}Tc 0.03 Gy to ROI



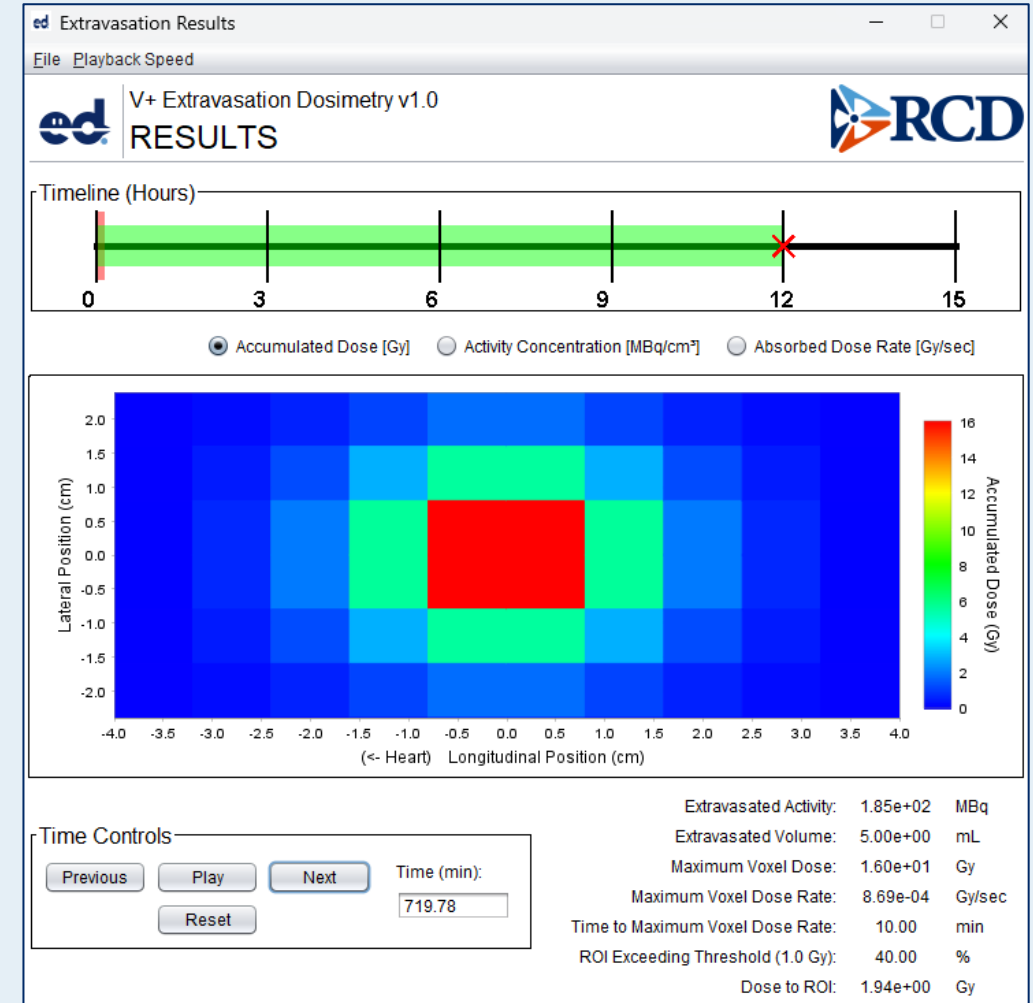
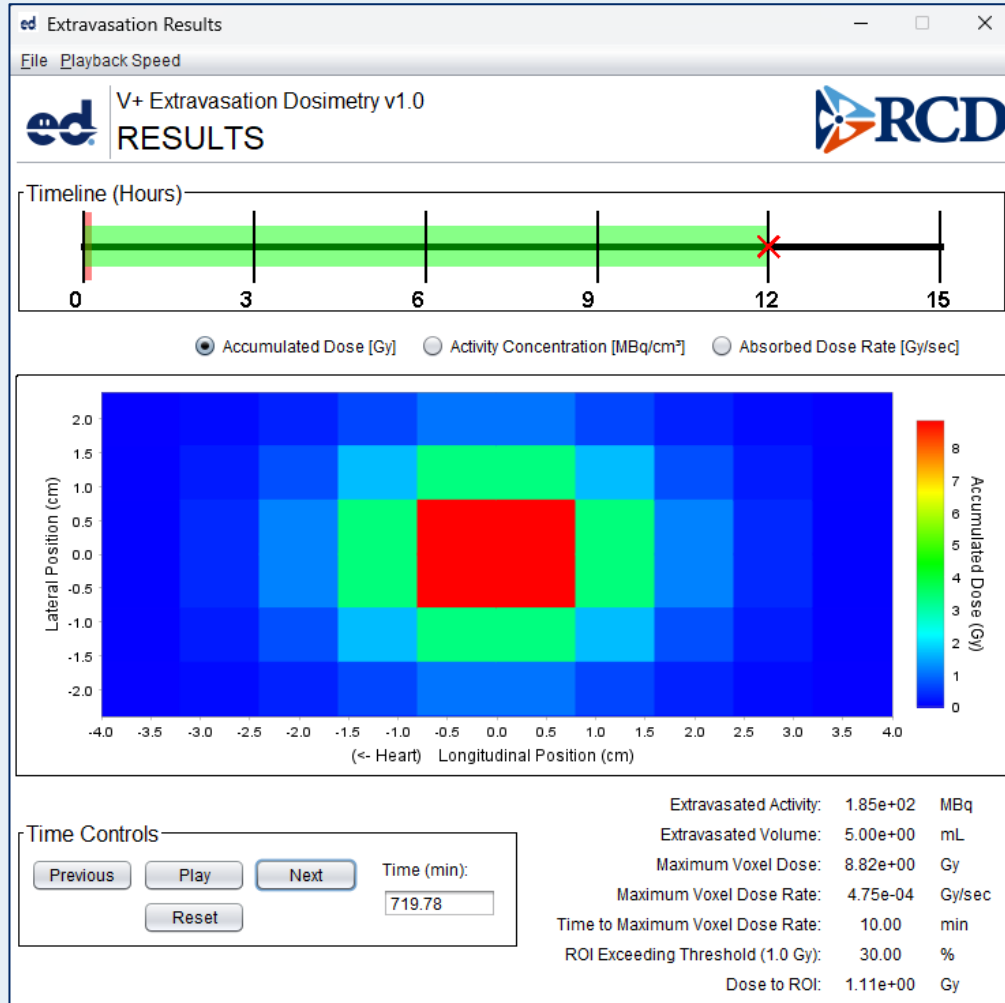
5-mCi Activity in Trapped Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.01 cm²/h



⁹⁰Y 1.1 Gy to ROI

¹³¹I 1.9 Gy to ROI



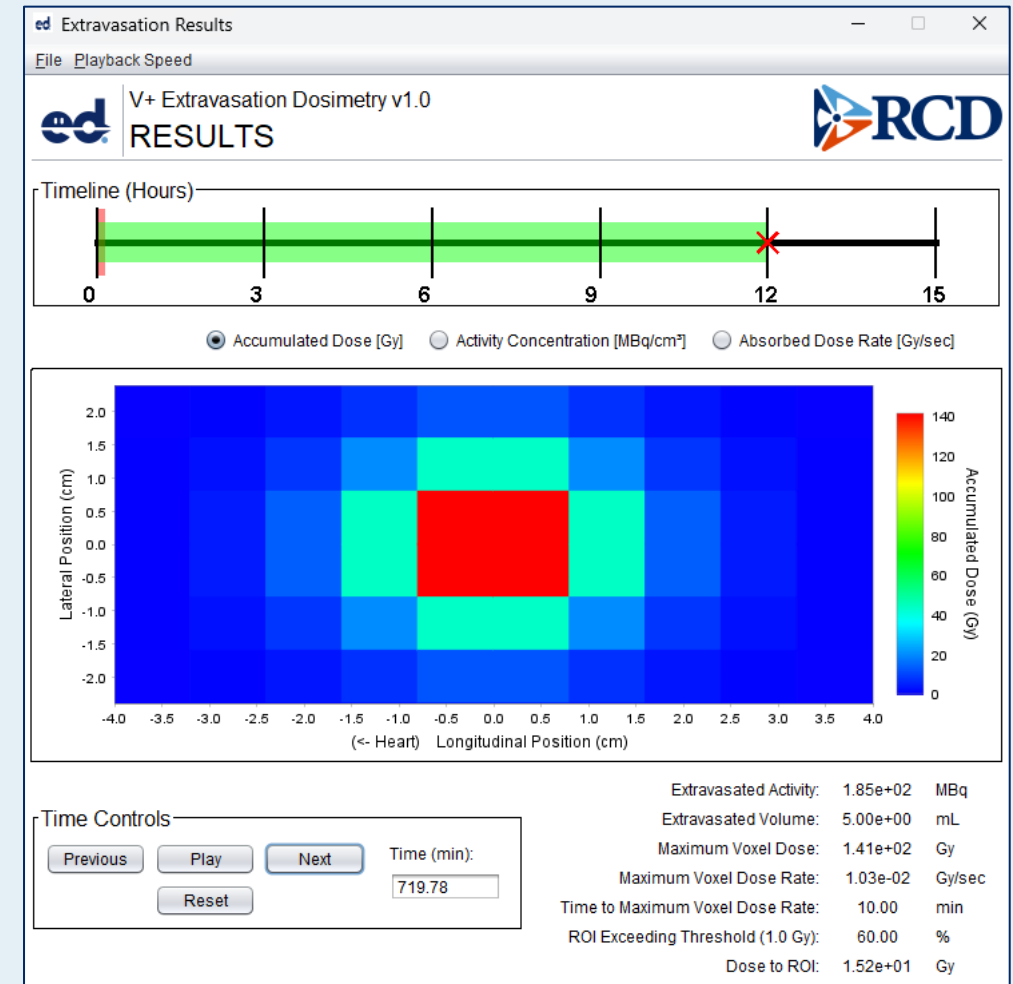
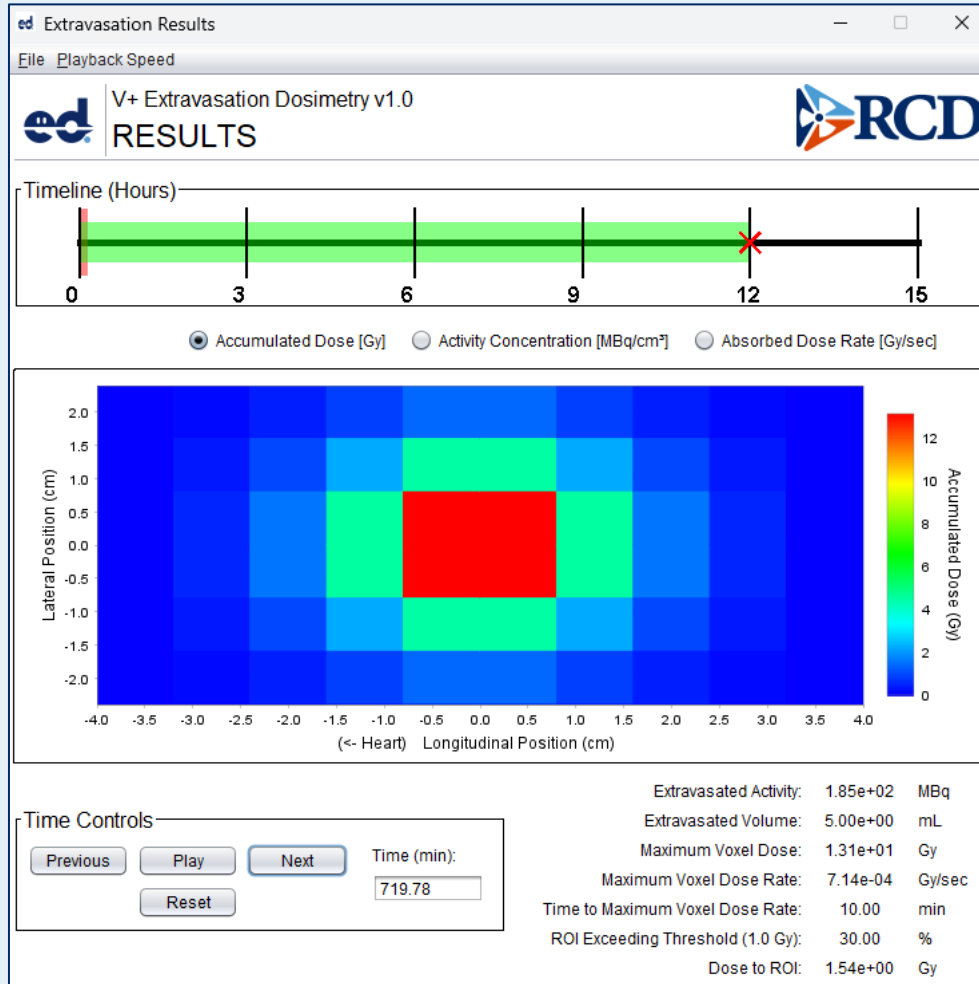
5-mCi Activity in Trapped Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.01 cm²/h



¹⁷⁷Lu 1.5 Gy to ROI

²¹¹At 15 Gy to ROI

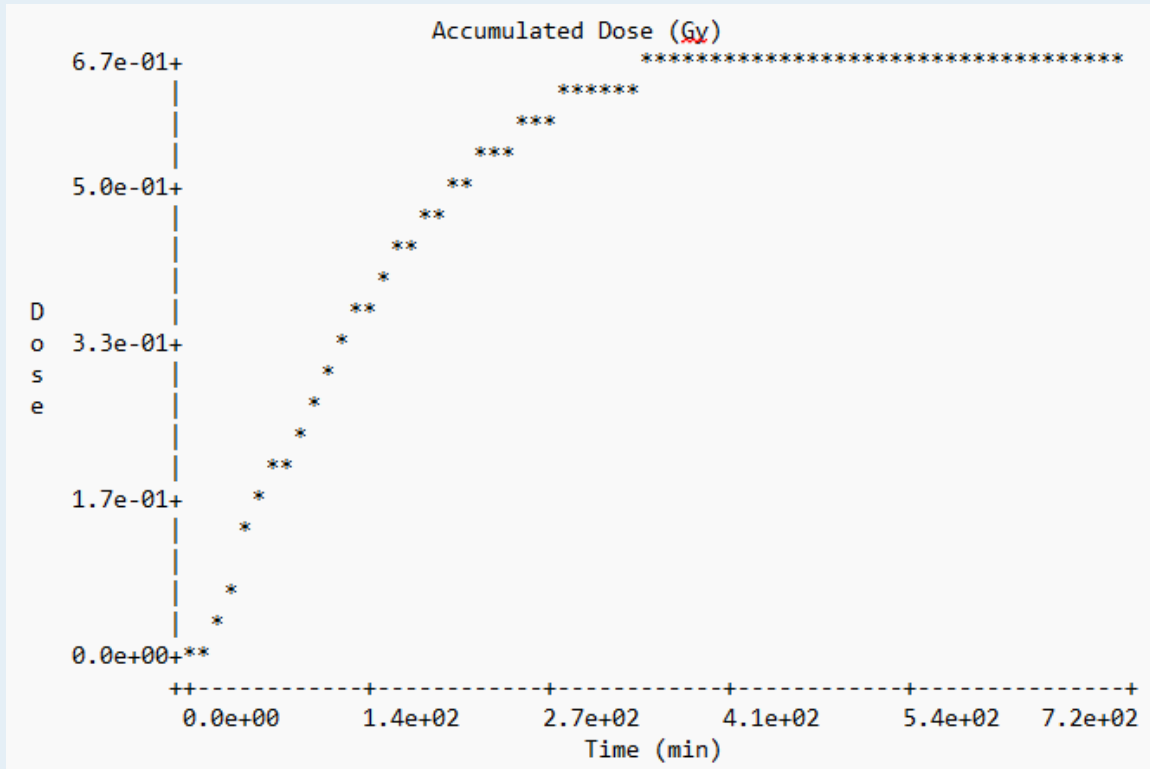


5-mCi Activity in Trapped Extravasated Fluid, Different Radionuclide

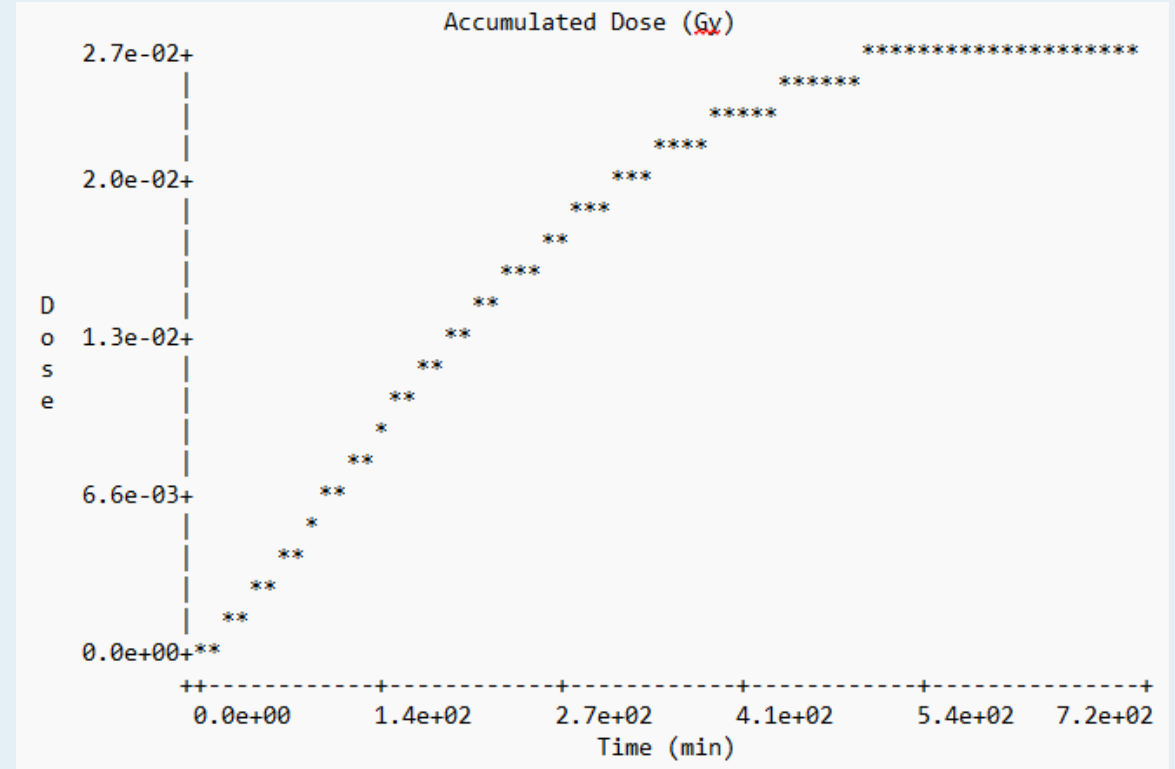
Lateral Transmissivity 0.01 cm²/h



¹⁸F 0.67 Gy to ROI



^{99m}Tc 0.03 Gy to ROI



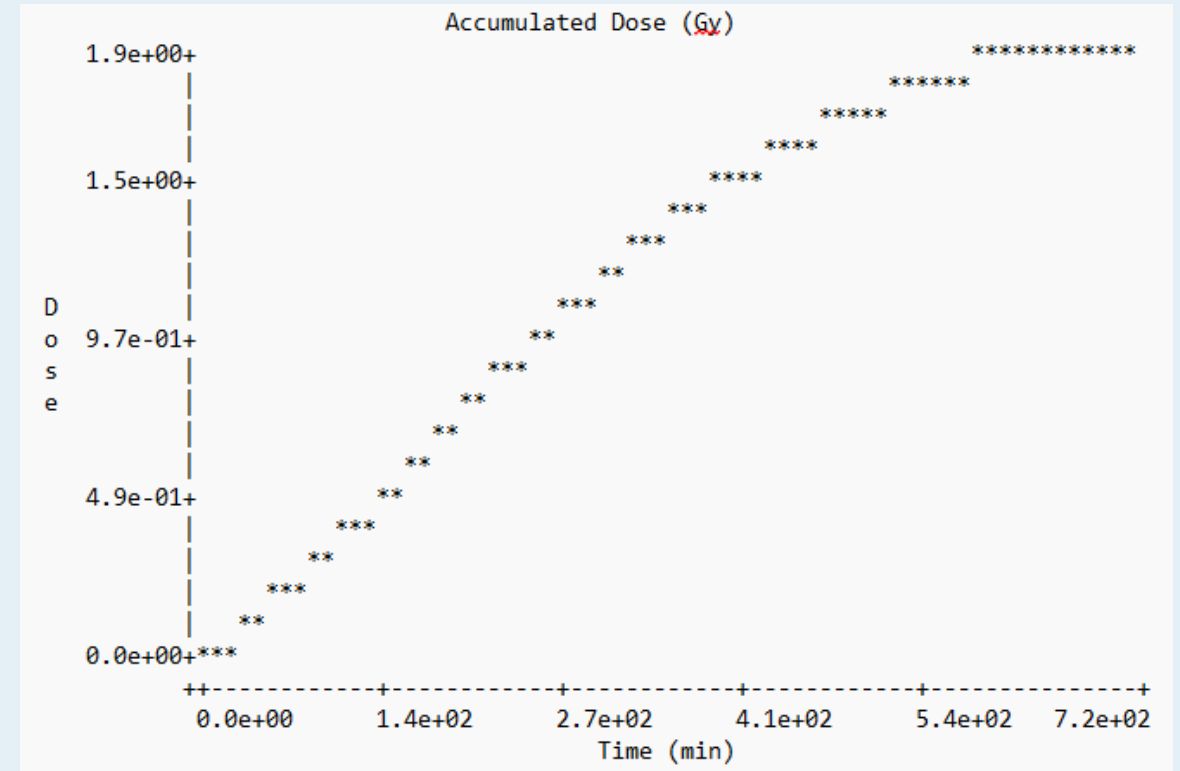
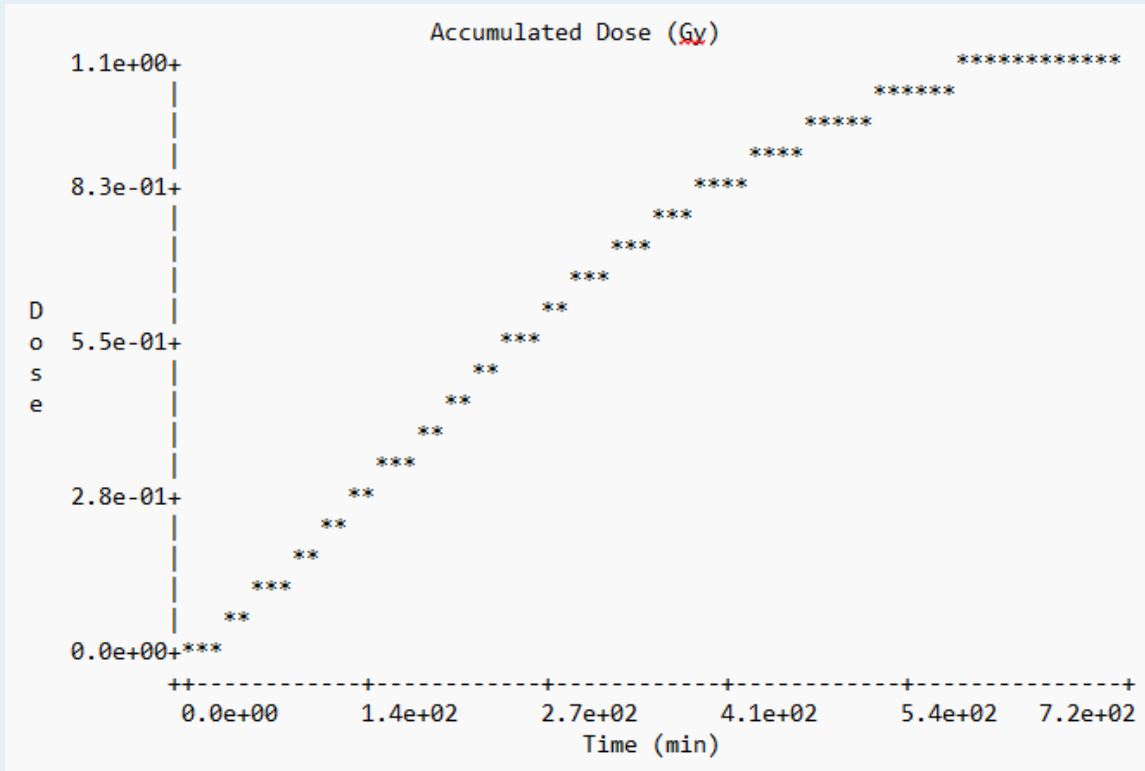
5-mCi Activity in Trapped Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.01 cm²/h



⁹⁰Y 1.1 Gy to ROI

¹³¹I 1.9 Gy to ROI



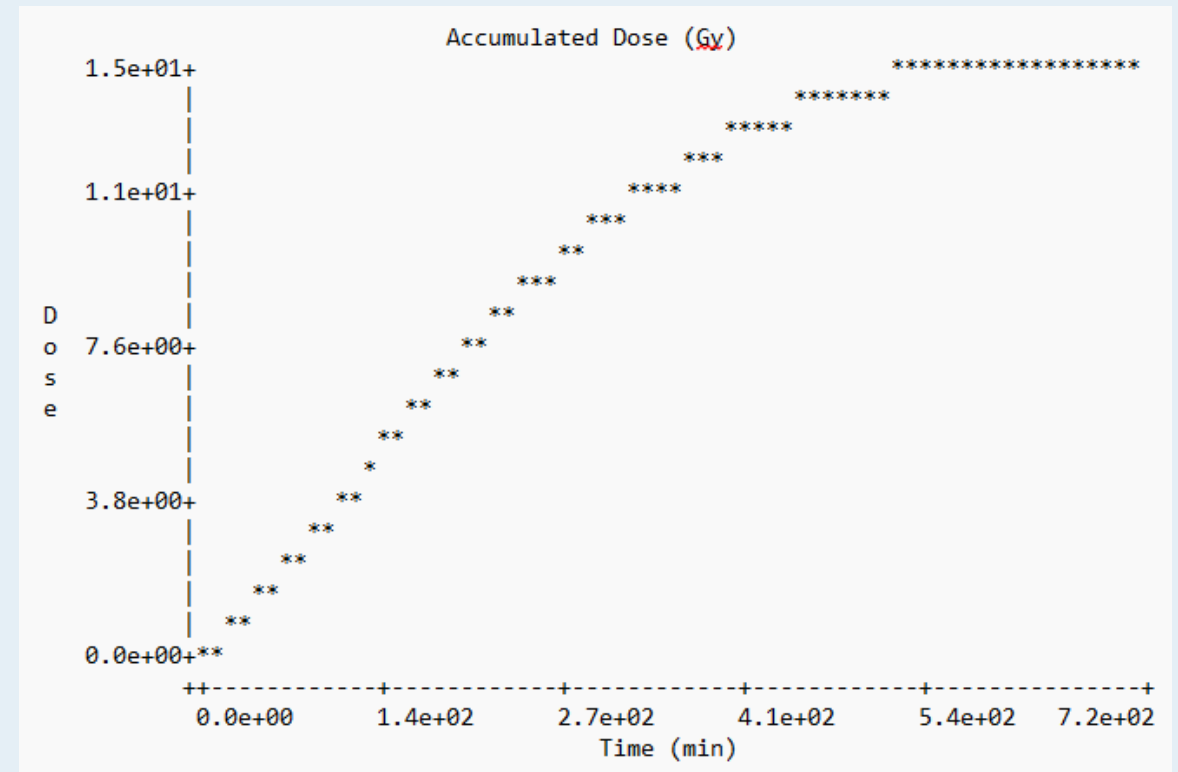
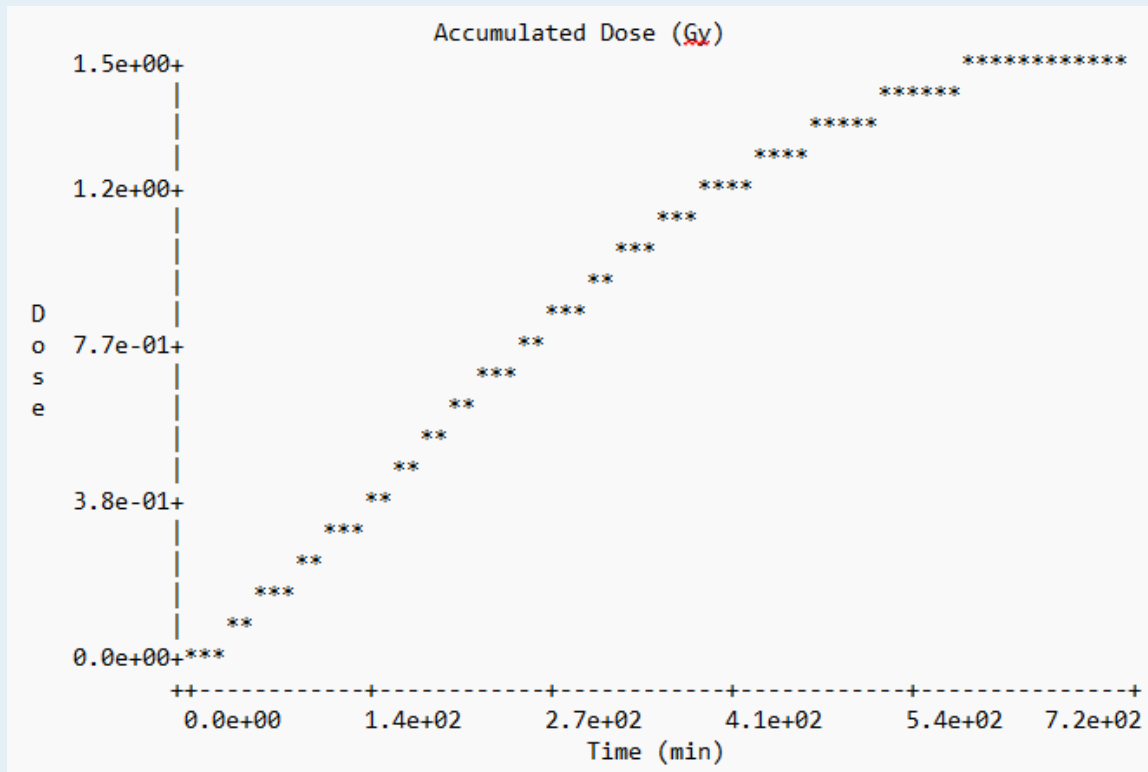
5-mCi Activity in Trapped Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.01 cm²/h



¹⁷⁷Lu 1.5 Gy to ROI

²¹¹At 15 Gy to ROI



Example VI: Lateral fluid flow with different radionuclides

5-mCi Activity in Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.1 cm²/h

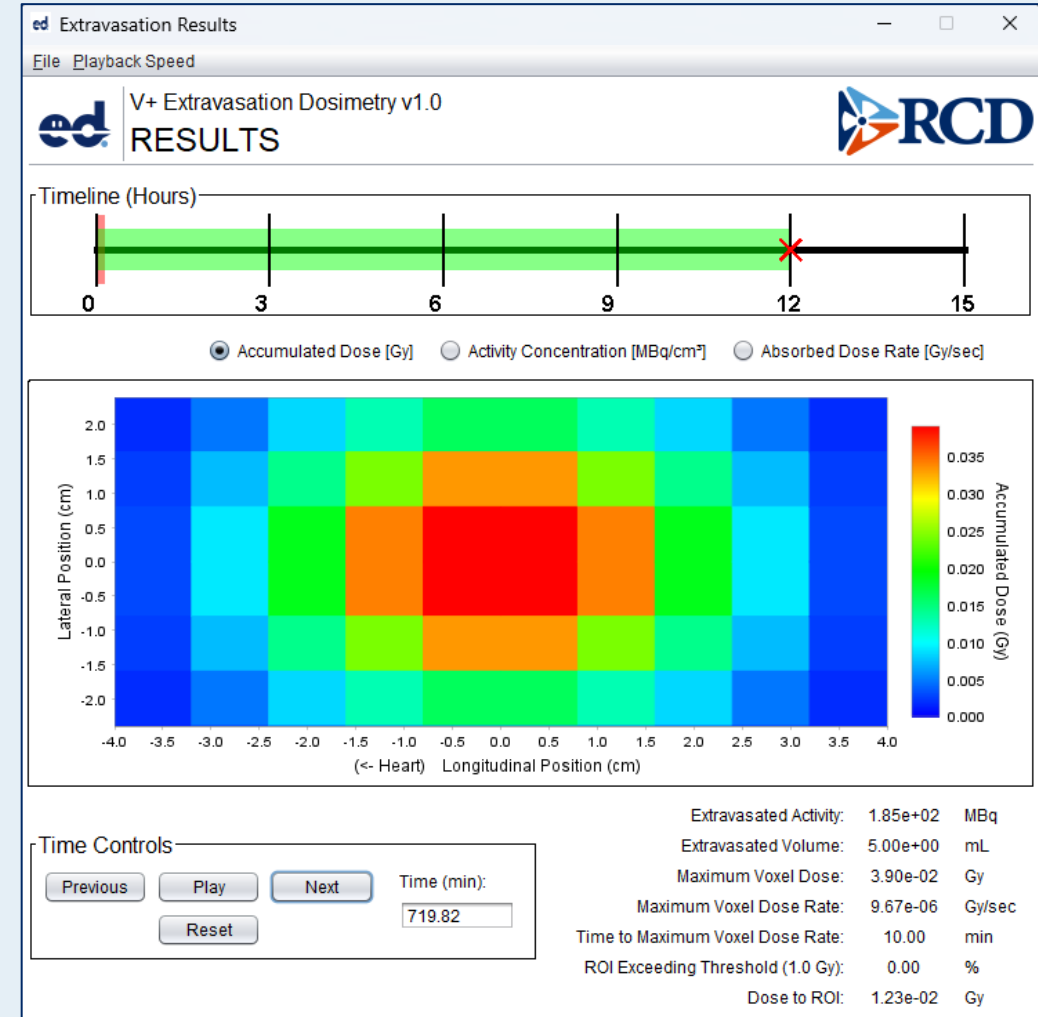
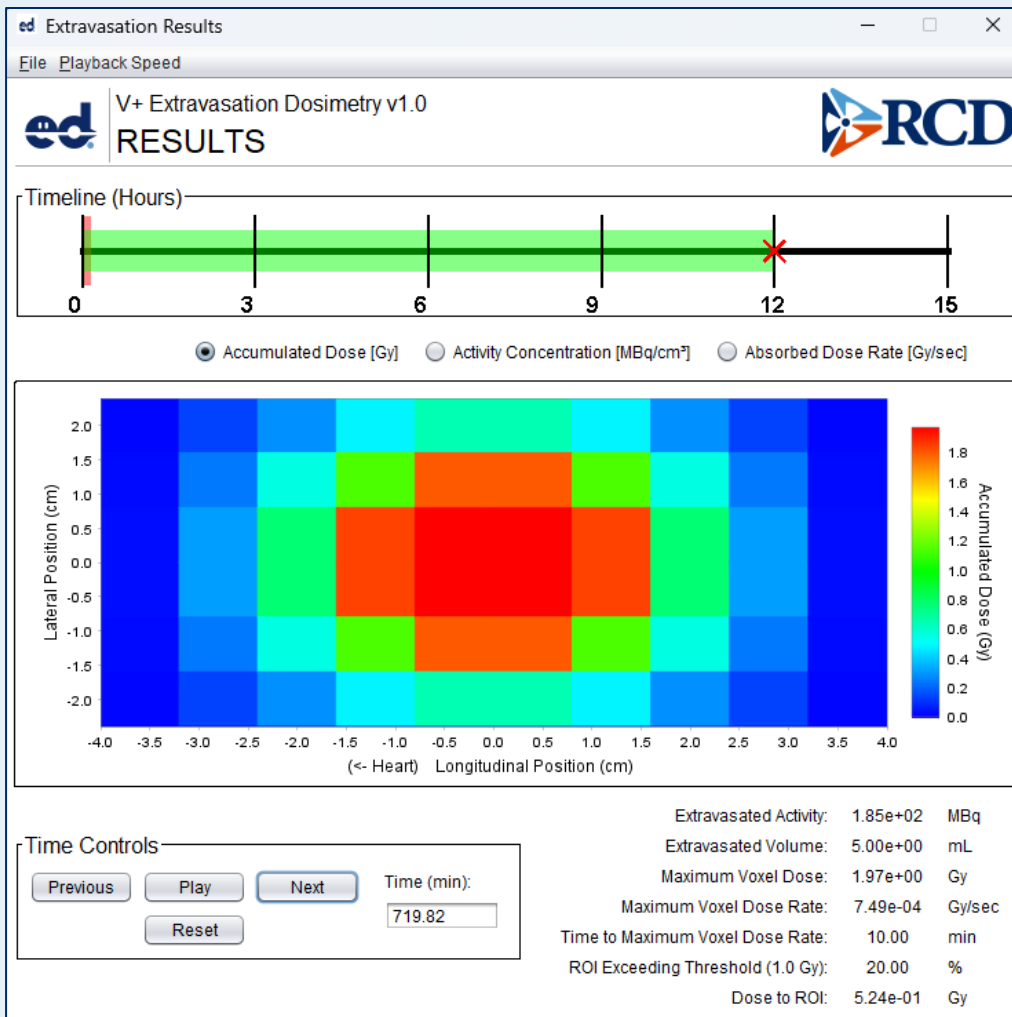


¹⁸F 0.52 Gy to ROI

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 cm²/h

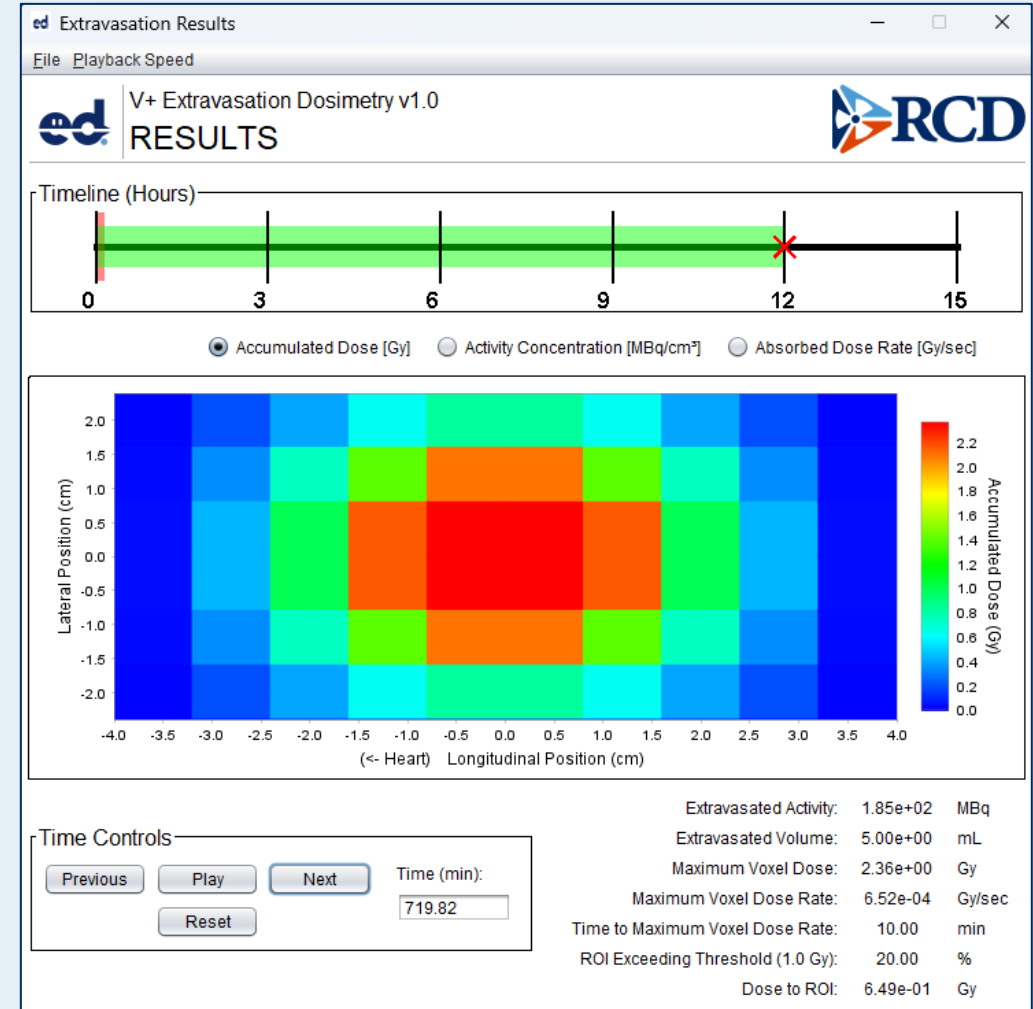
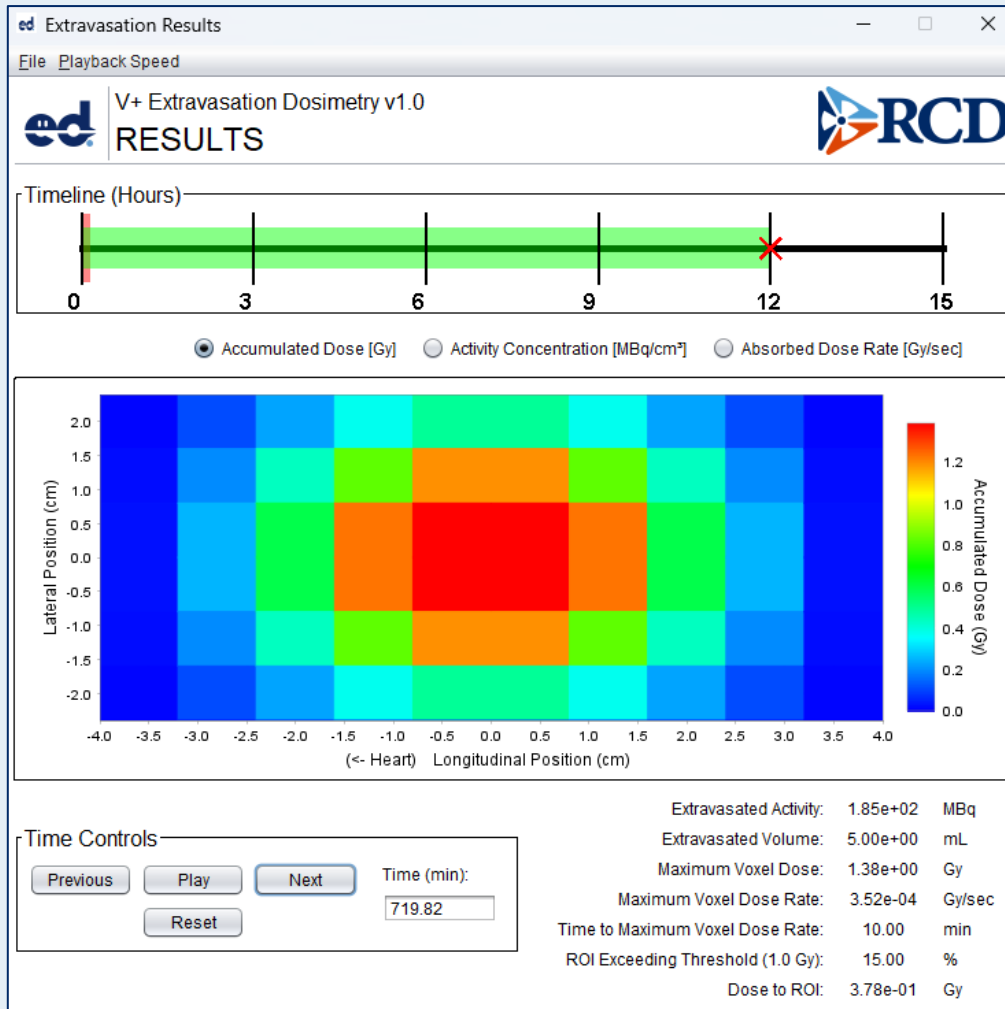


⁹⁰Y 0.38 Gy to ROI

Physical half-life 64 h

¹³¹I 0.65 Gy to ROI

Physical half-life 192 h



5-mCi Activity in Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.1 cm²/h

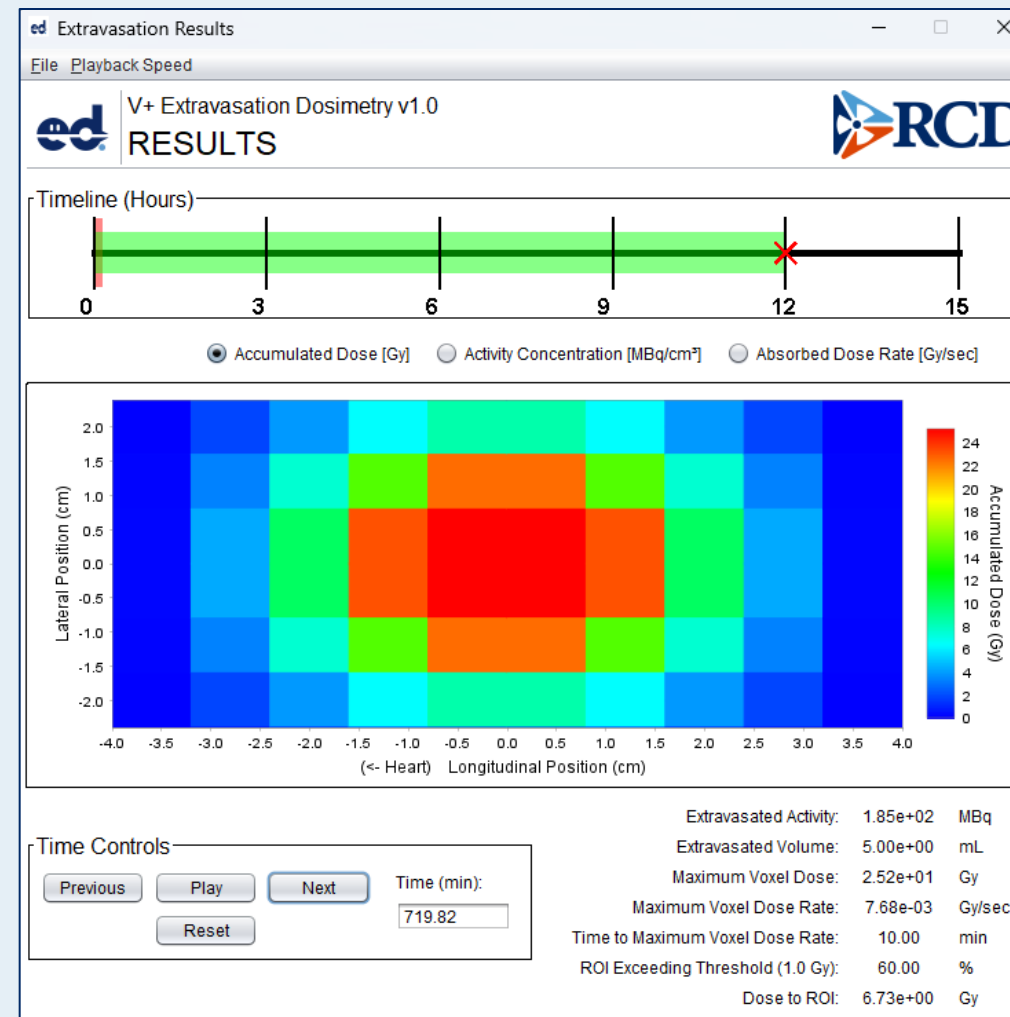
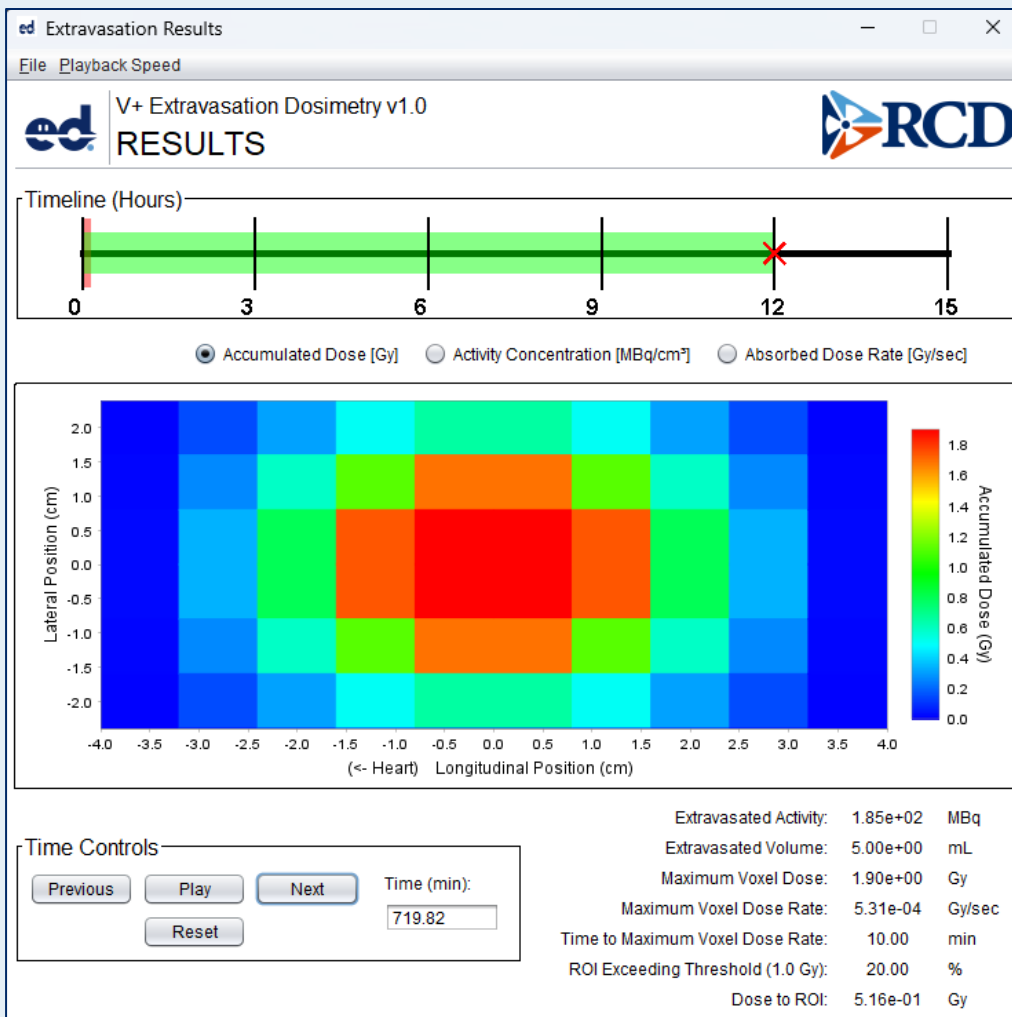


¹⁷⁷Lu 0.52 Gy to ROI

Physical half-life 160 h

²¹¹At 6.7 Gy to ROI

Physical half-life 7.2 h



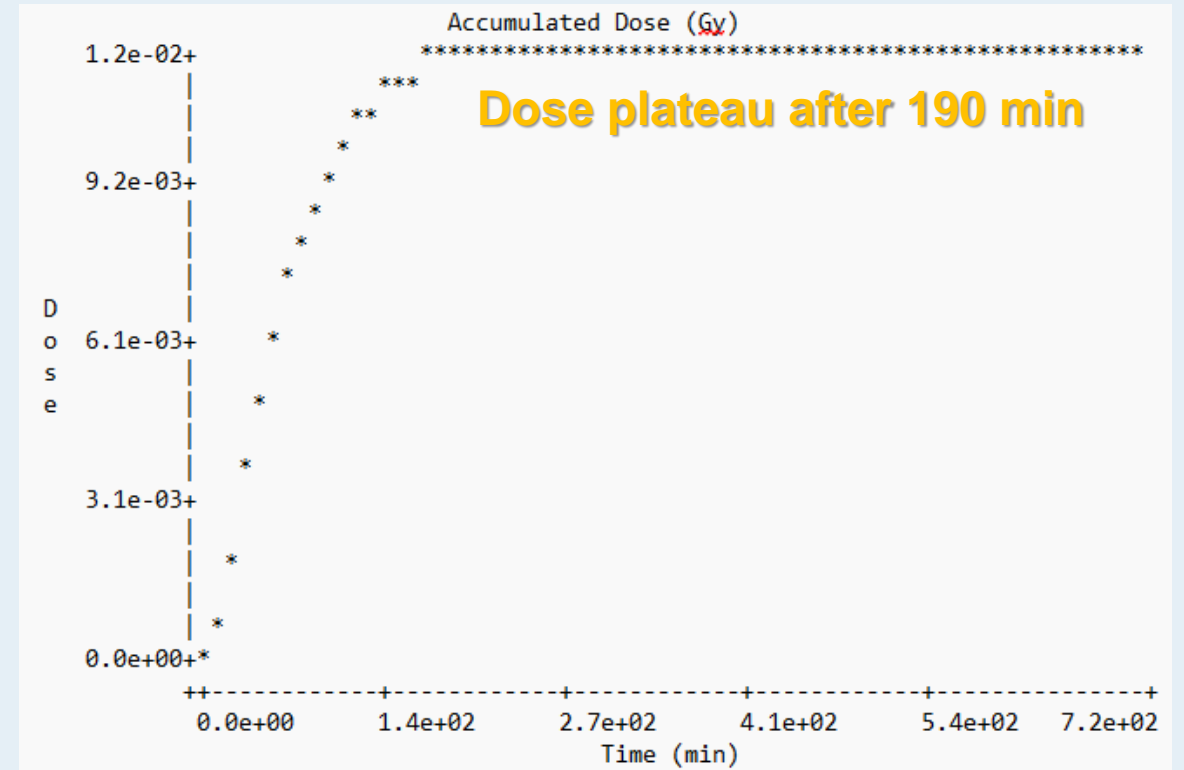
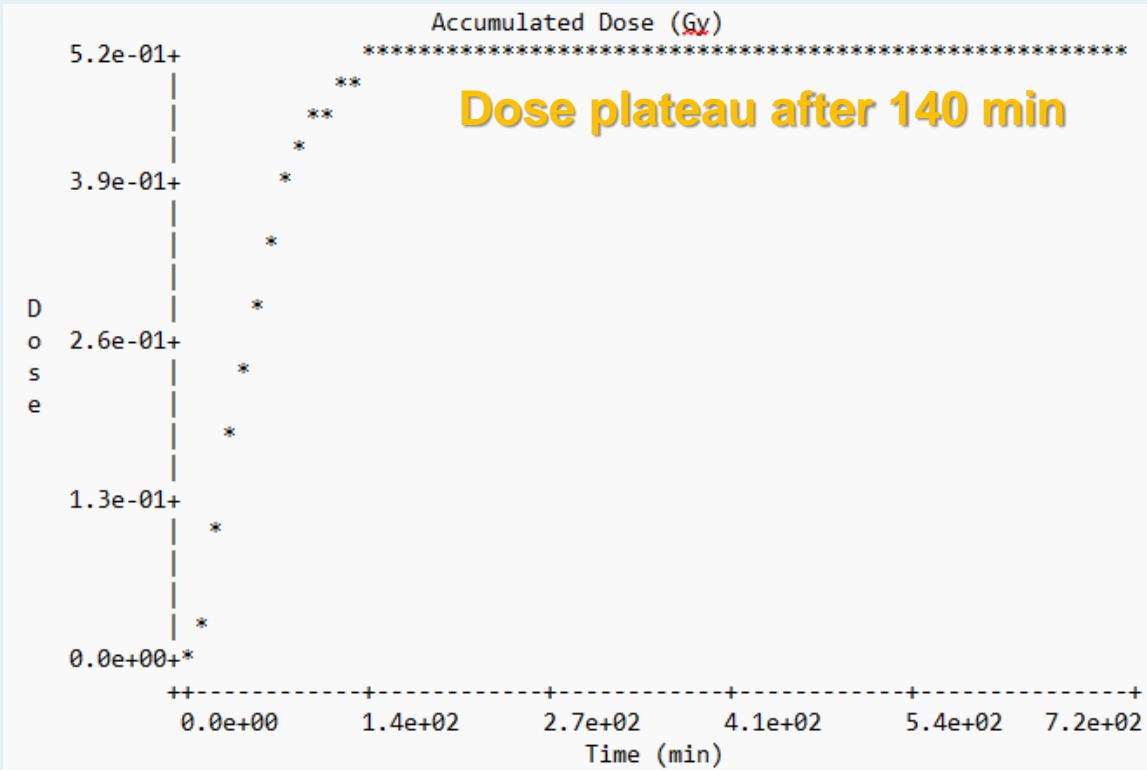
5-mCi Activity in Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.1 cm²/h



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

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



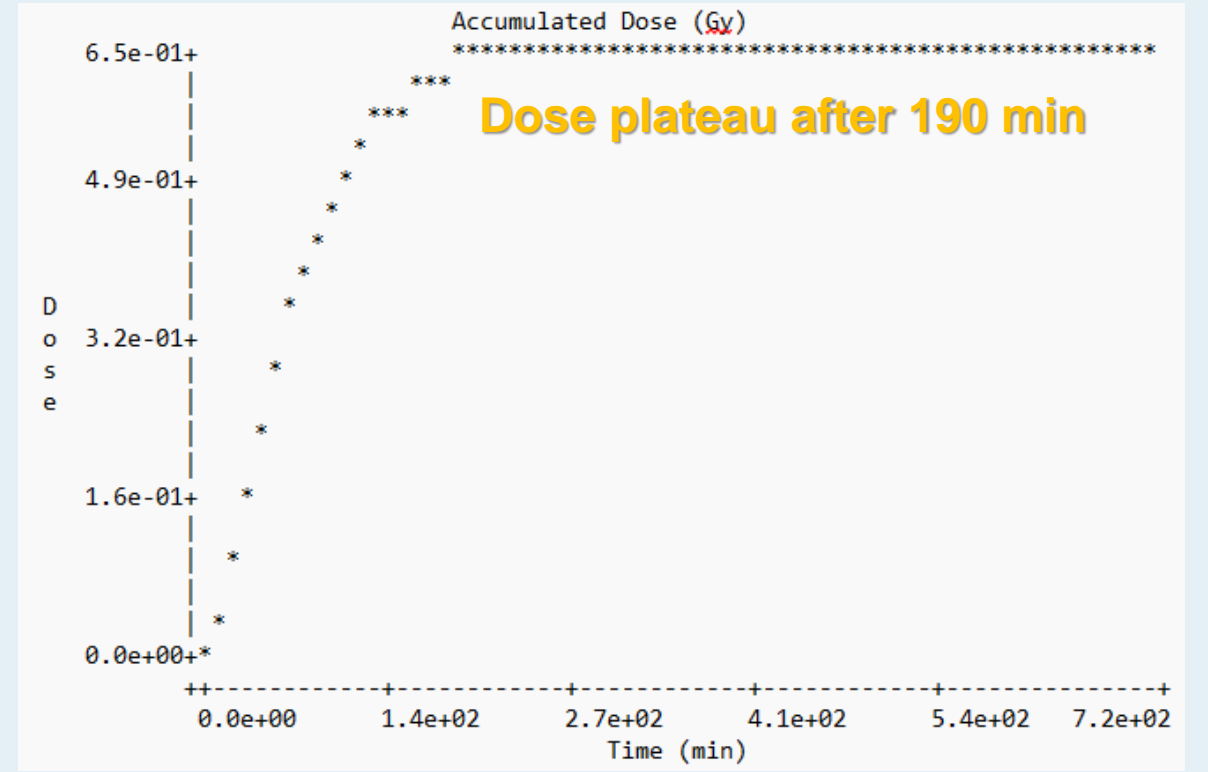
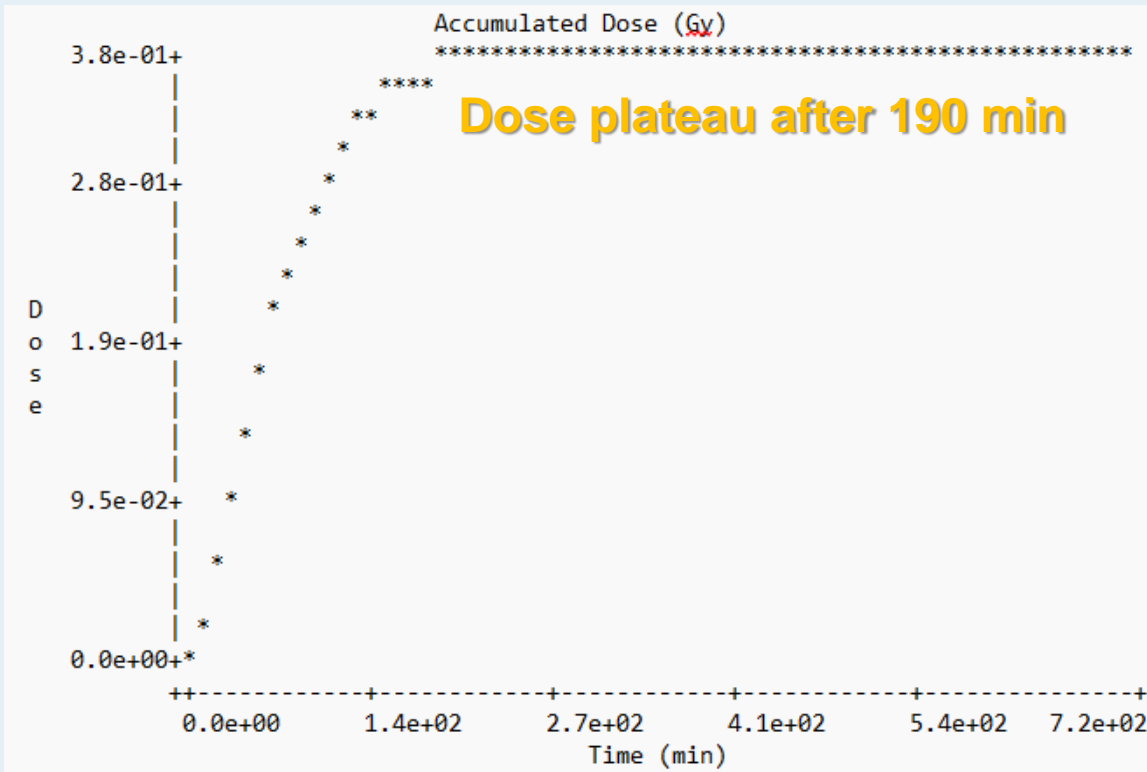
5-mCi Activity in Extravasated Fluid, Different Radionuclide

Lateral Transmissivity 0.1 cm²/h



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

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

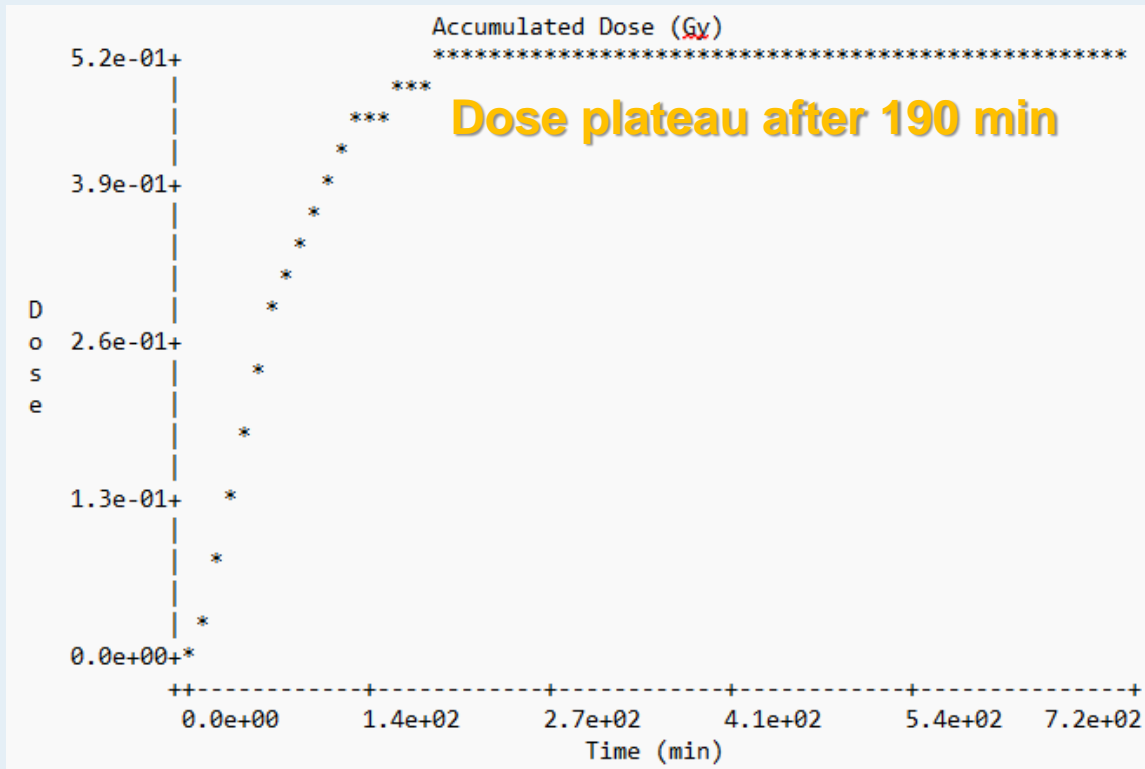


5-mCi Activity in Extravasated Fluid, Different Radionuclide

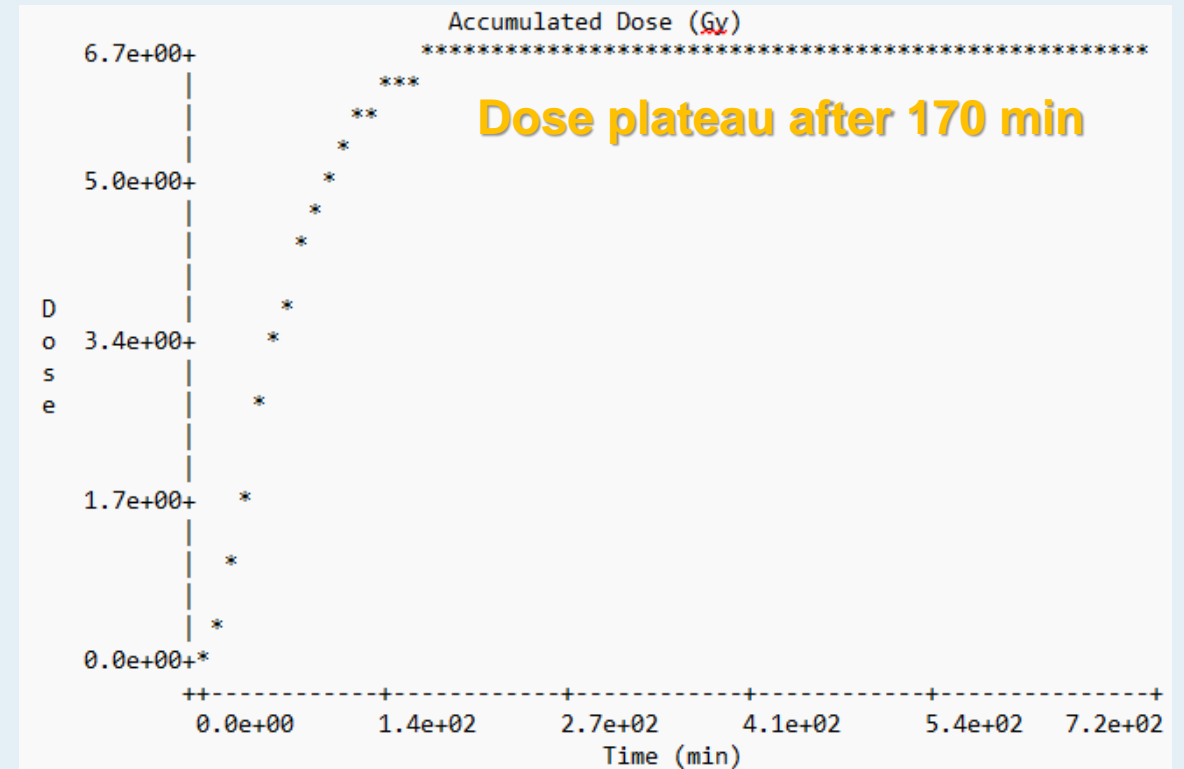
Lateral Transmissivity 0.1 cm²/h



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



²¹¹At 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 cm²/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)

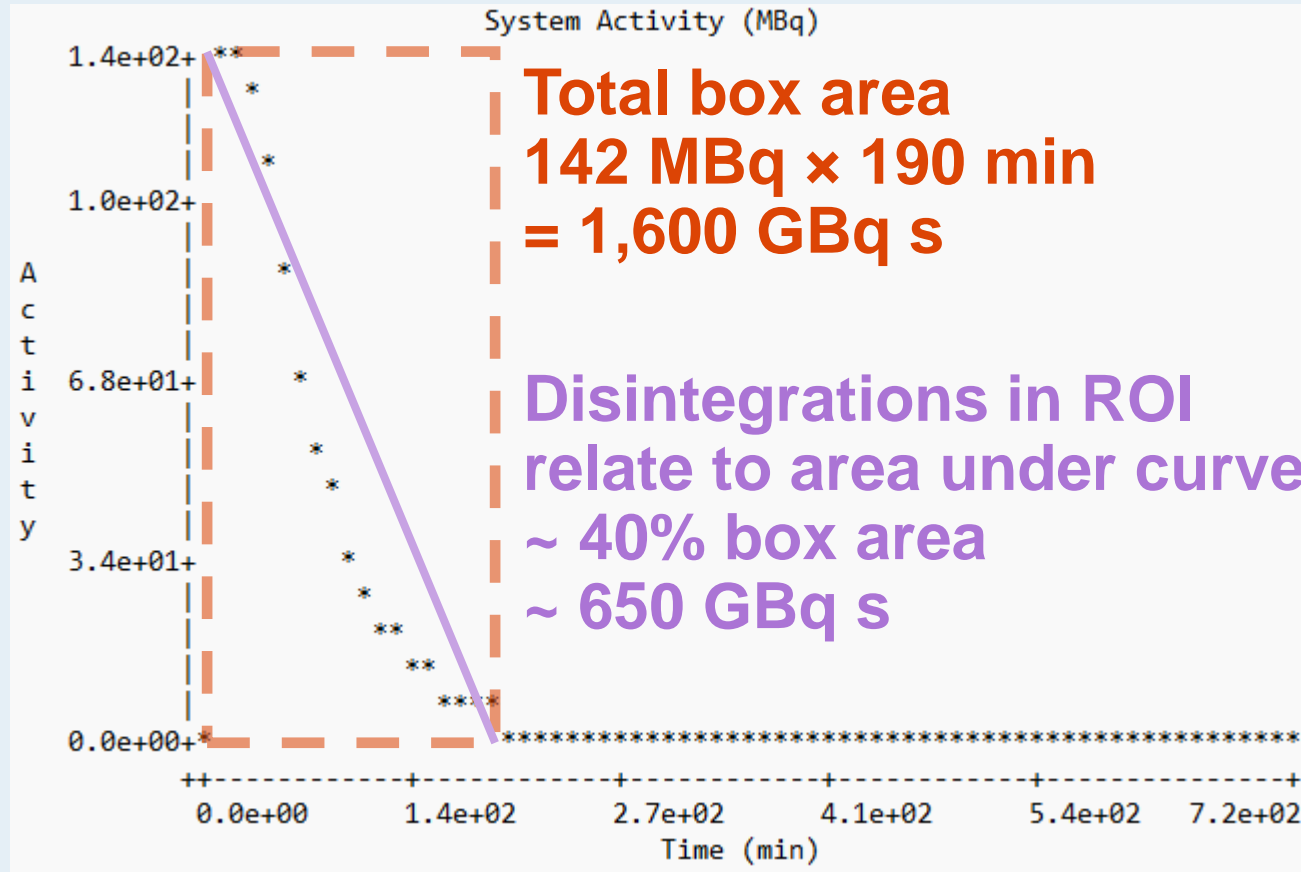
Nuclide	Half-life	Decay mode	Emitted energy (MeV/nt)			
			Alpha	Electron	Photon	Total
F-18	109.77 m	ECB+	–	0.2416	0.9886	<1.2302 *
Tc-99m	6.015 h	ITB-	–	0.0162	0.1266	<0.1428 *
Y-90	64.10 h	B-	–	0.9331	<E-04	<0.9331 *
I-131	8.02070 d	B-	–	0.1918	0.3828	<0.5746 *
Lu-177	6.647 d	B-	–	0.1479	0.0351	0.1830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



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

Shayma Mohammed* and Adel Trabelsi

¹⁸F positron range publication

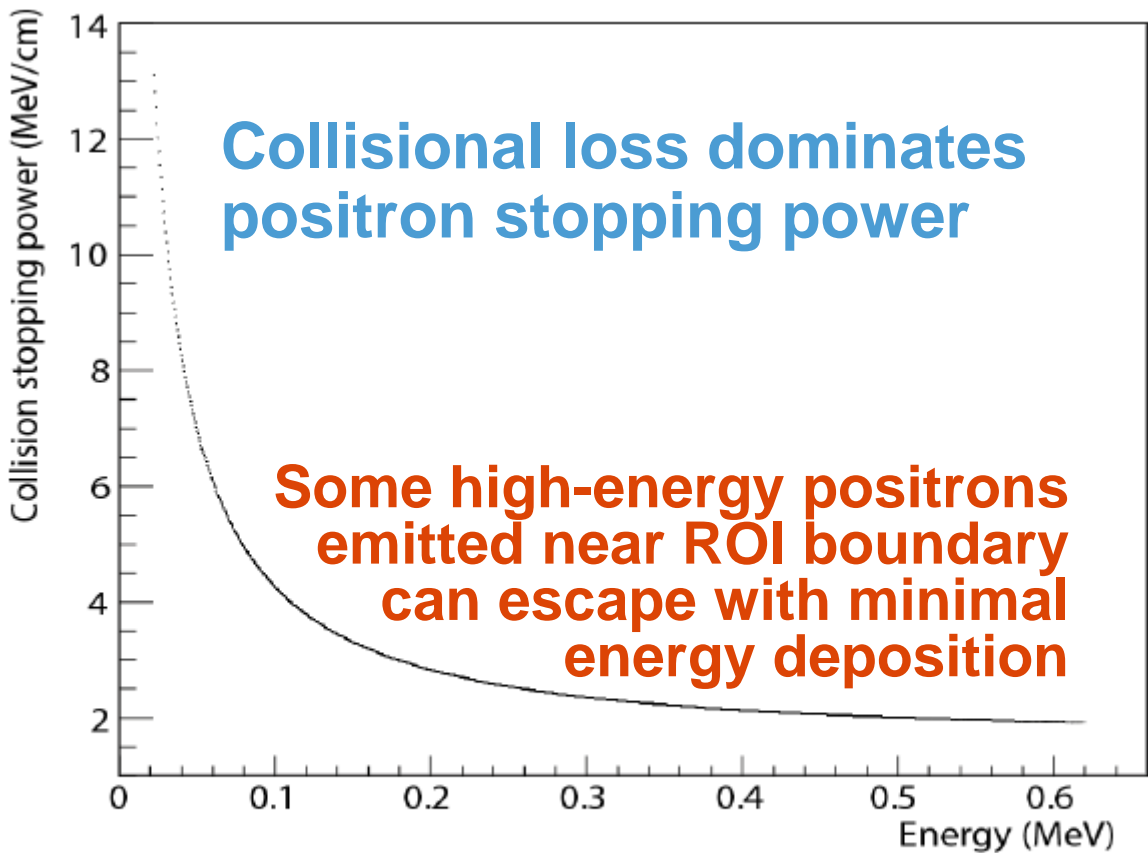


Figure 4. Shows the water collision energy loss values for 50000 ¹⁸F tracks²⁴.

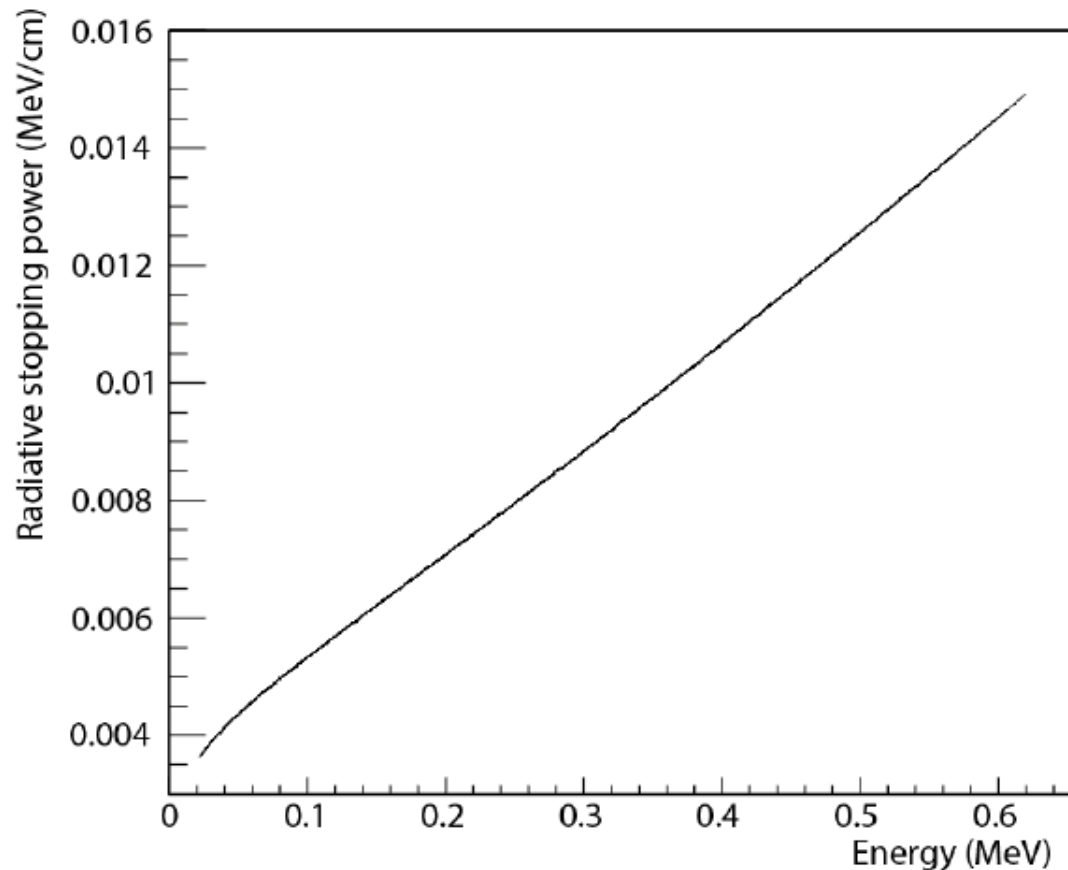


Figure 5. Shows the radiative energy loss values of the water for 50000 ¹⁸F tracks²⁴.



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

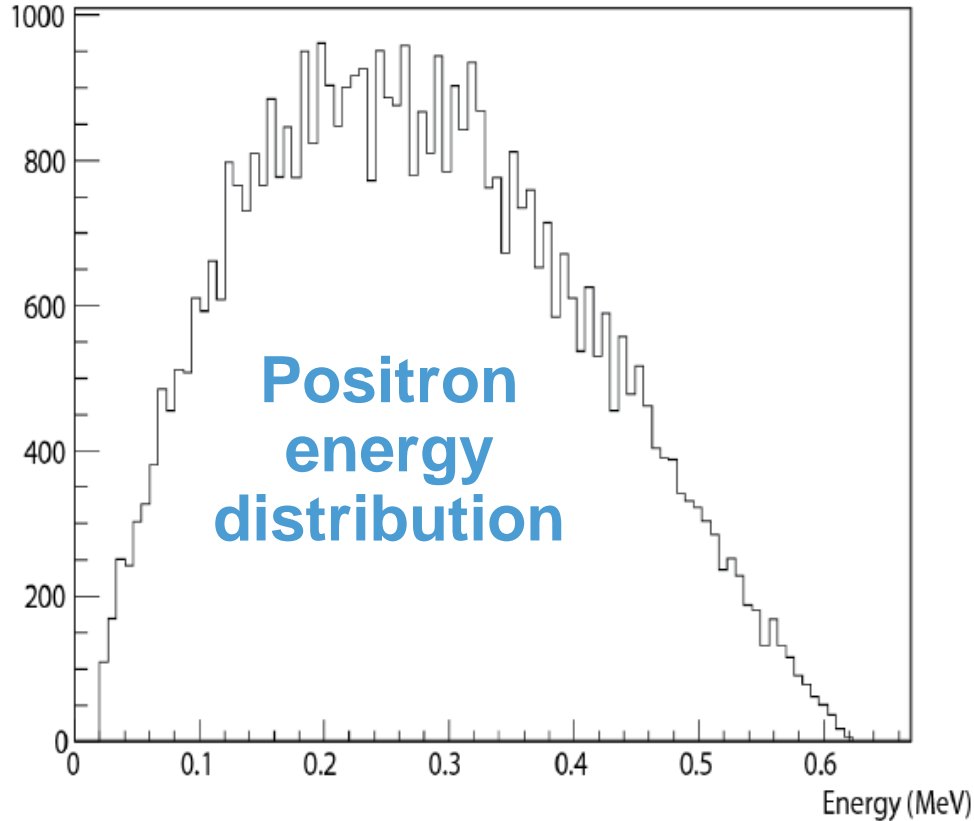
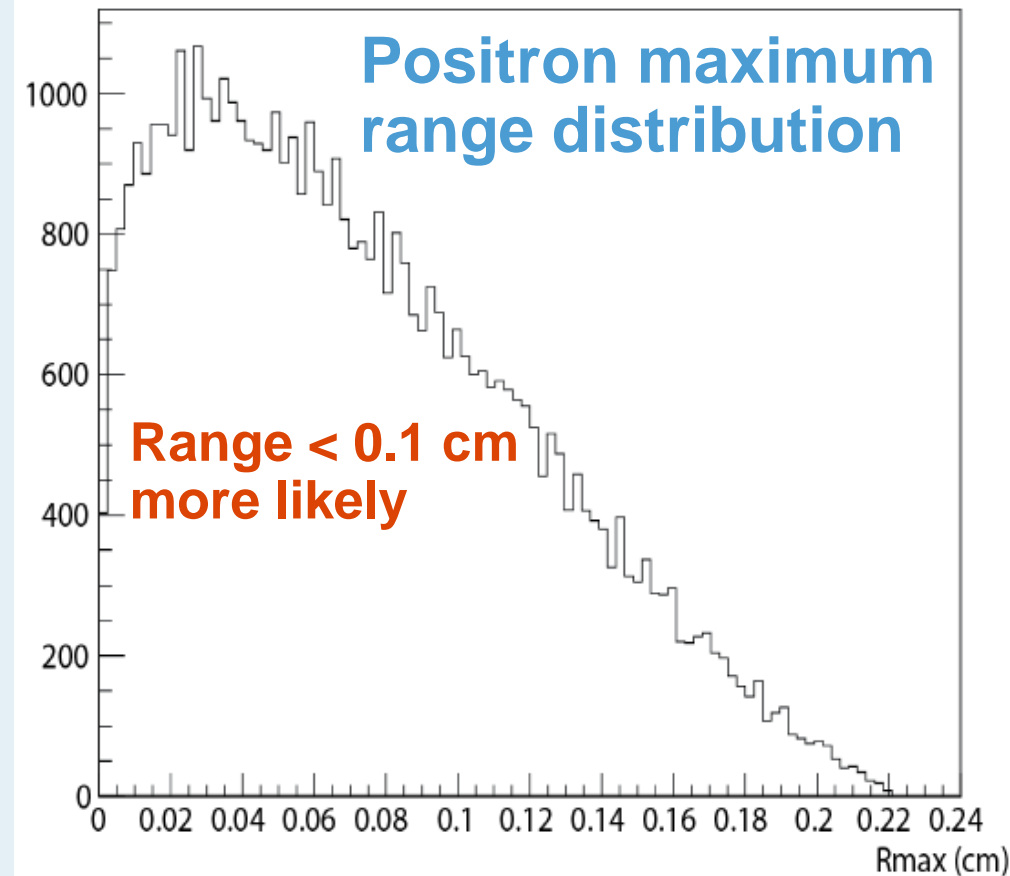


Figure 1. The positron energy Spectrum for ^{18}F located in water (50000 simulated positron trajectories) using the G4 UniformRand() random function.



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* $R_{\max} \approx 0.1$ 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)

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

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

Approximate ^{18}F energy deposited in ROI

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

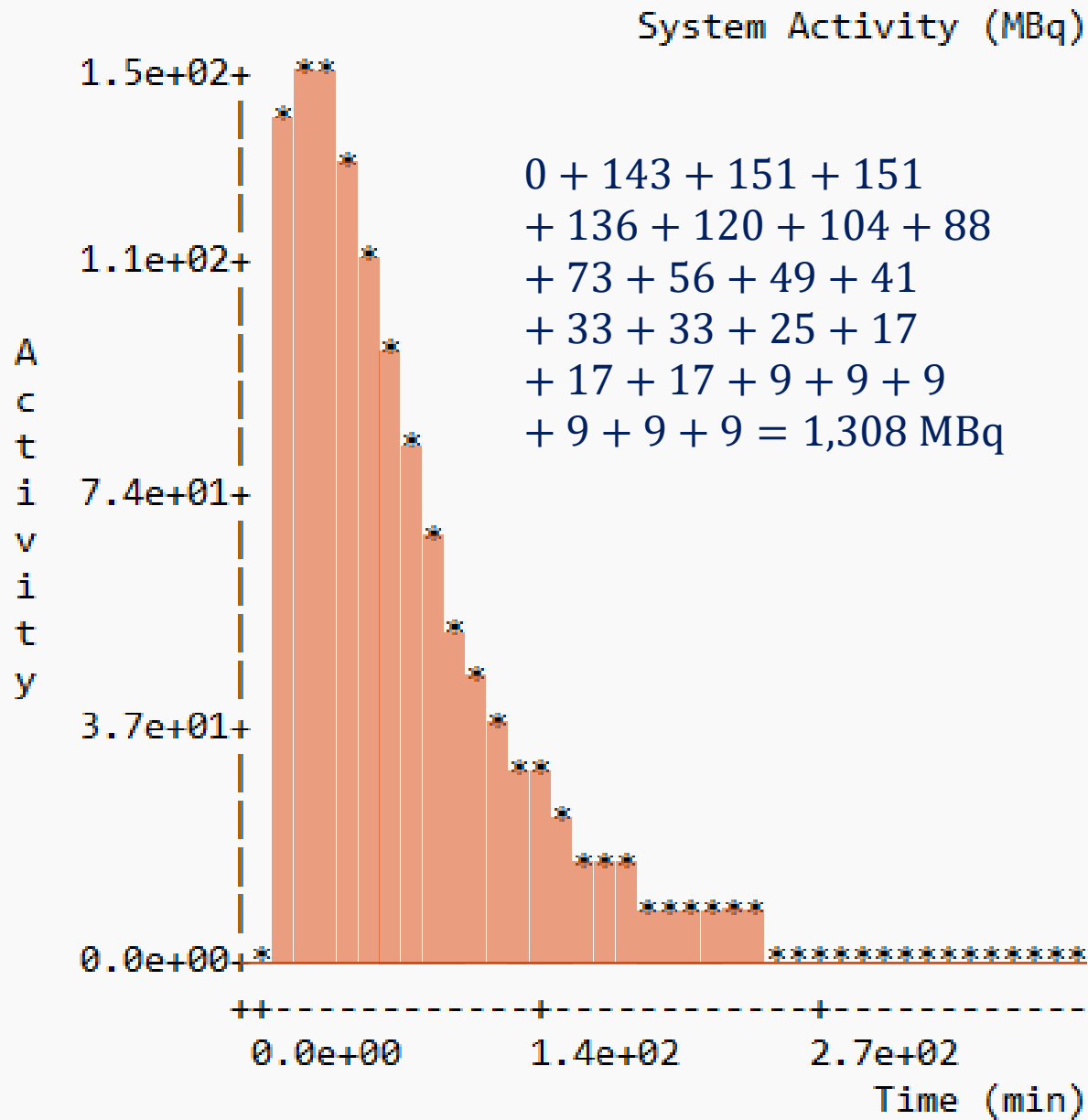


$$D_{ROI} \approx \frac{650 \times 10^9 \text{ Bq s} \times 0.21 \frac{\text{MeV}}{\text{Bq s}}}{(4.8 \text{ cm} \times 8.0 \text{ cm} \times 0.8 \text{ cm}) \left(1.1 \frac{\text{g}}{\text{cm}^3}\right) \left(6.24 \times 10^9 \frac{\text{MeV}}{\text{Gy g}}\right)} \approx 0.64 \text{ Gy}$$

V+ result: 0.52 Gy

19% lower dose

²¹¹At Dose to ROI



Area under curve equals disintegrations in ROI

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

- 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

²¹¹At Dose to ROI (parent emissions only)



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

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



ed Extravasation Dosimetry v1.0

File Mode Help

V+ Extravasation Dosimetry v1.0
MODEL INPUTS

Source and Concentration Inputs

Database: ICRP-38 ICRP-107
 Nuclide:
 Concentration: MBq/mL
 Flow Rate: mL/min

Layer Inputs

Tissue Model: Homogeneous Heterogeneous
 Number of Layers:
 Layer 1
 Effective Tissue Thickness: mm
 Lateral Transmissivity: cm²/h

Transport Inputs

Dose Notification Threshold: Gy
 Region Width: cm
 Region Length: cm
 Vertical Transmissivity: cm²/h
 Fluid Diffusivity: cm²/h
 Voxel Side Length: mm

Diagram

Timeline Calculate Results

ed 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

Edit Selected Event (#2)

Type:

Day

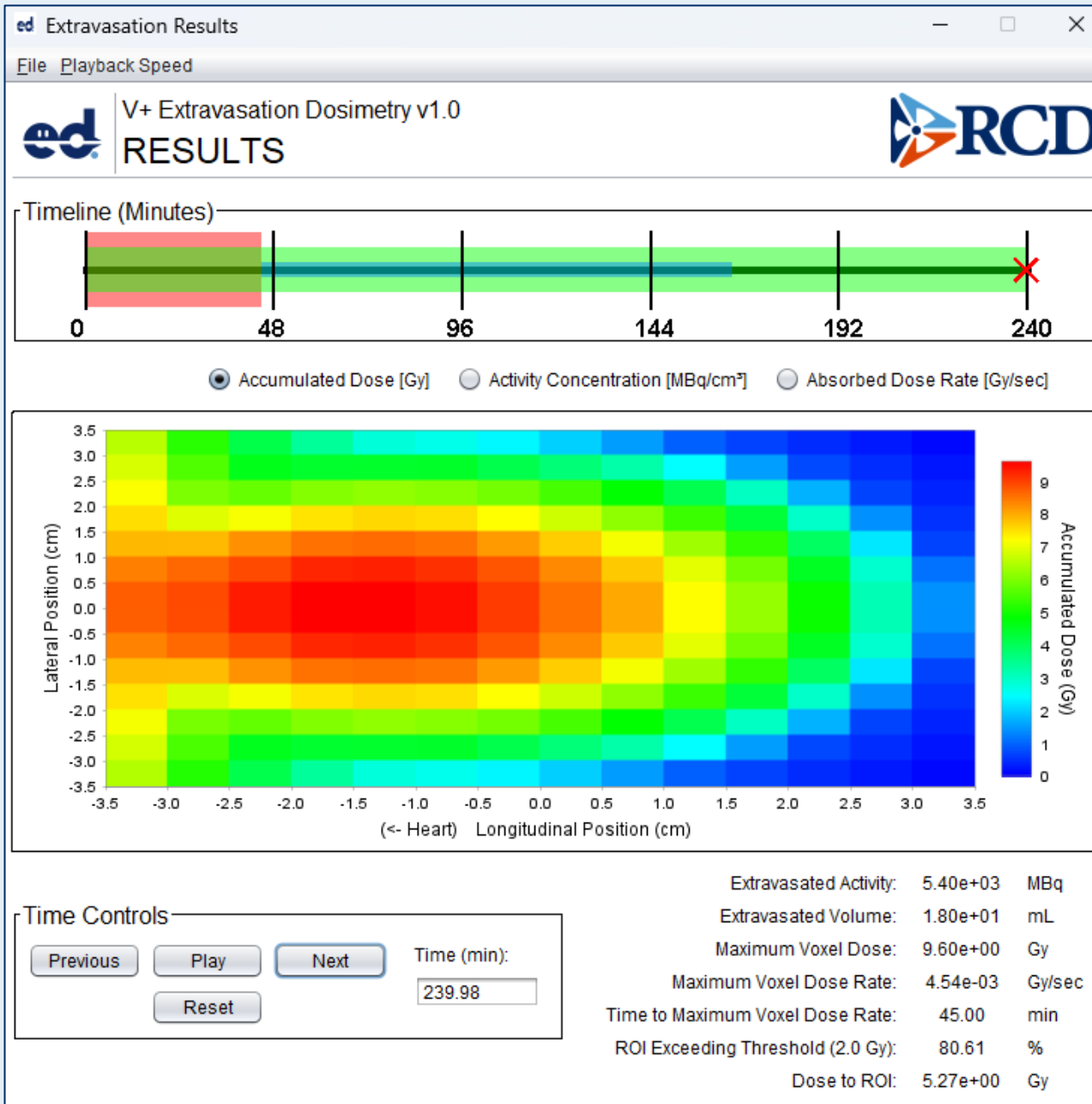
Start Time:

End Time:

Duration: Hours

Elevation: Degrees

Timeline (Minutes)



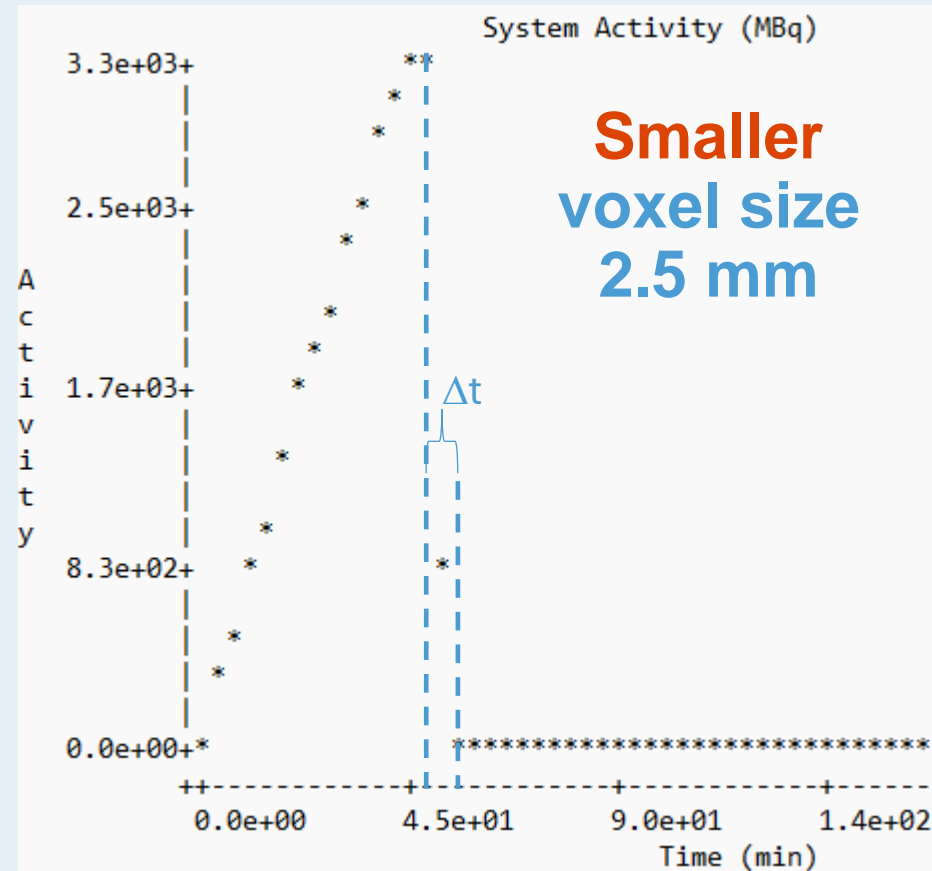
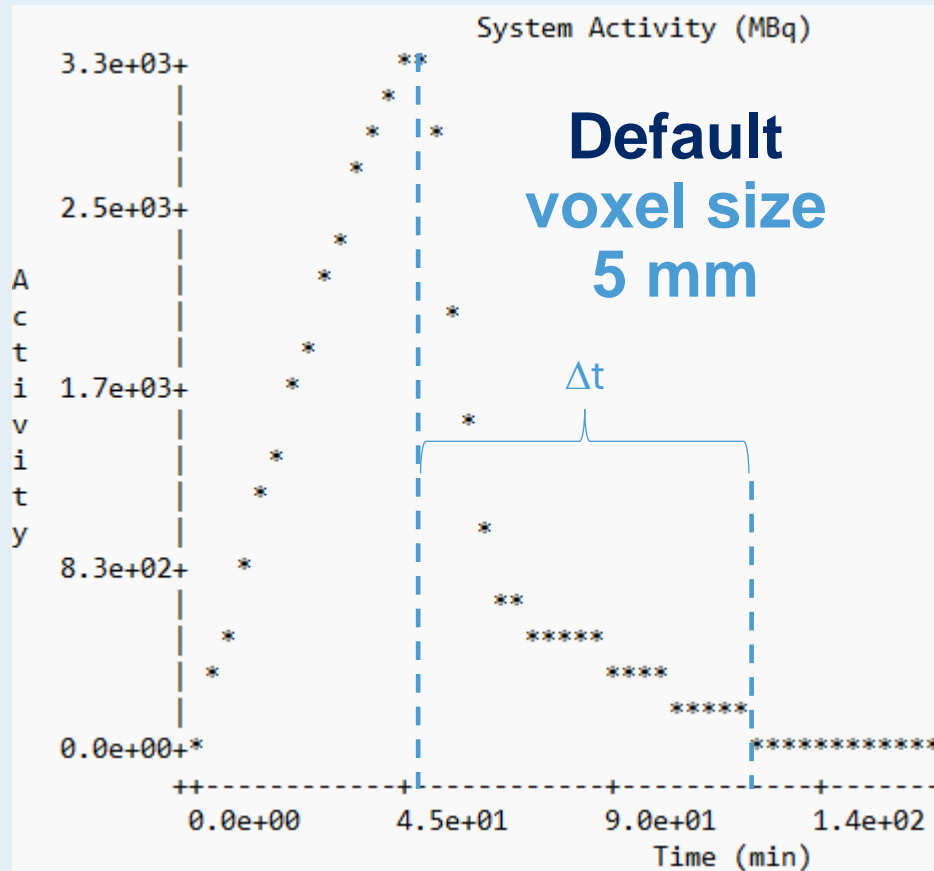
Gravity from limb elevation influences fluid movement and accumulated dose distribution

Elevated end

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

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



Voxel size “influence” on lateral flow & biological clearance (cont’d)

Layer 1	Effective Tissue Thickness: 5.000 mm	Region Length: 7.000 cm
Lateral Transmissivity: 3.000 cm ² /h	Vertical Transmissivity: 1.000 cm ² /h	Fluid Diffusivity: 0.100 cm ² /h
	Voxel Side Length: 5.000 mm	

Layer 1	Effective Tissue Thickness: 5.000 mm	Region Length: 7.000 cm
Lateral Transmissivity: 3.000 cm ² /h	Vertical Transmissivity: 1.000 cm ² /h	Fluid Diffusivity: 0.100 cm ² /h
	Voxel Side Length: 2.500 mm	

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**

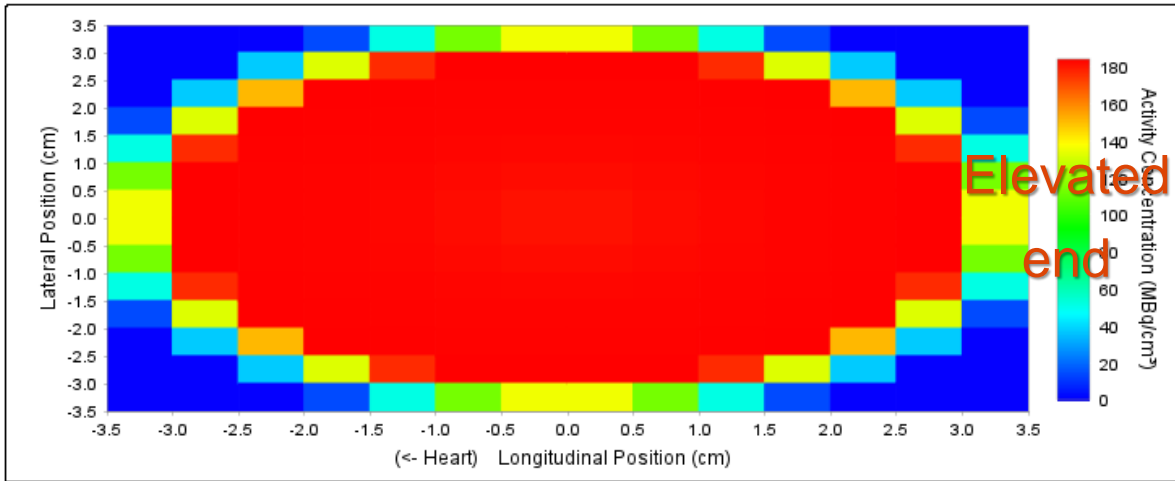
5-mm default voxels yield minimal ROI depletion in 7 min



Activity Concentrations

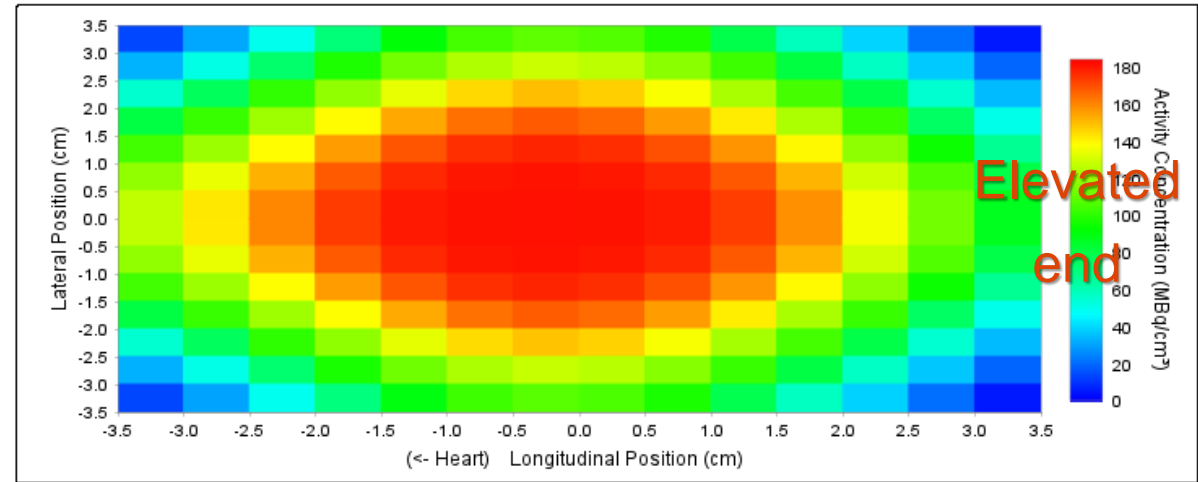
45 min

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



52 min

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



2.5-mm voxels yield substantial ROI depletion in 7 min



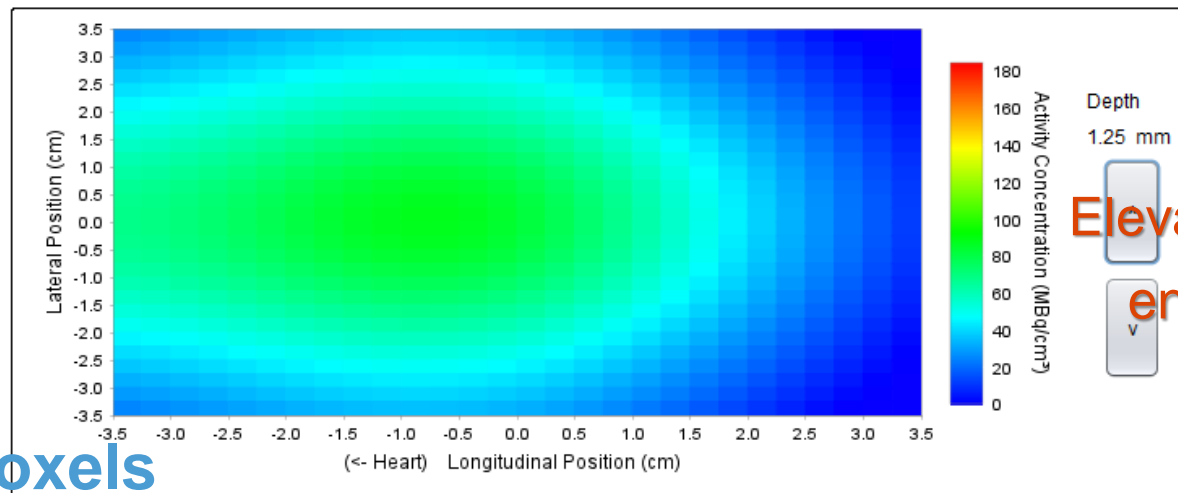
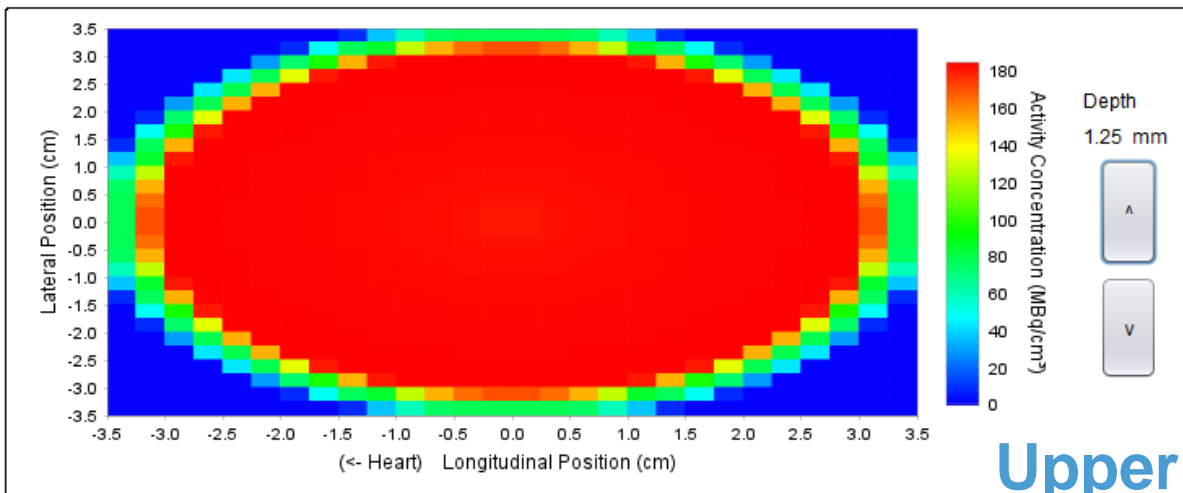
45 min

Activity Concentrations

52 min

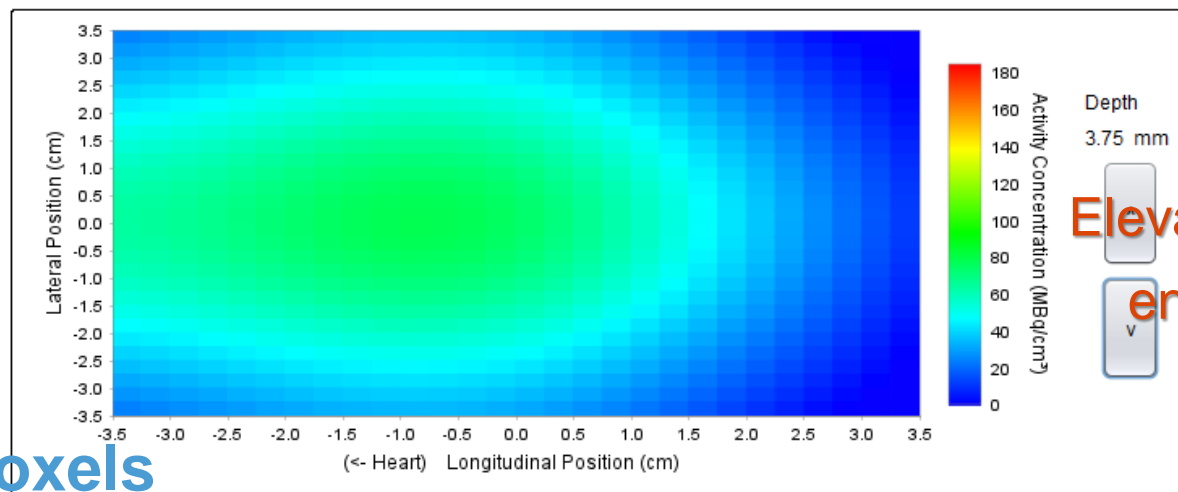
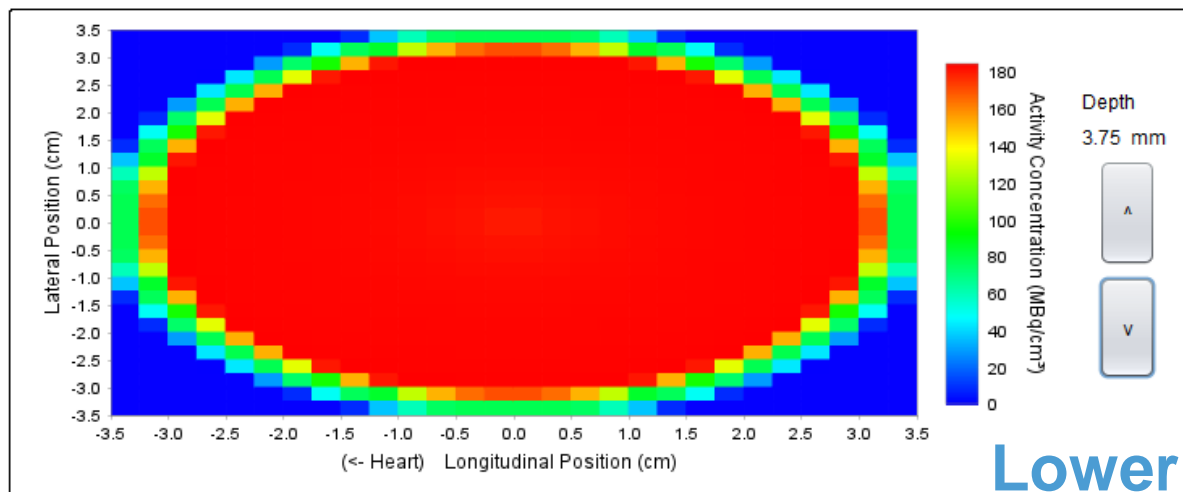
Accumulated Dose [Gy] Activity Concentration [MBq/cm³] Absorbed Dose Rate [Gy/sec]

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



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

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



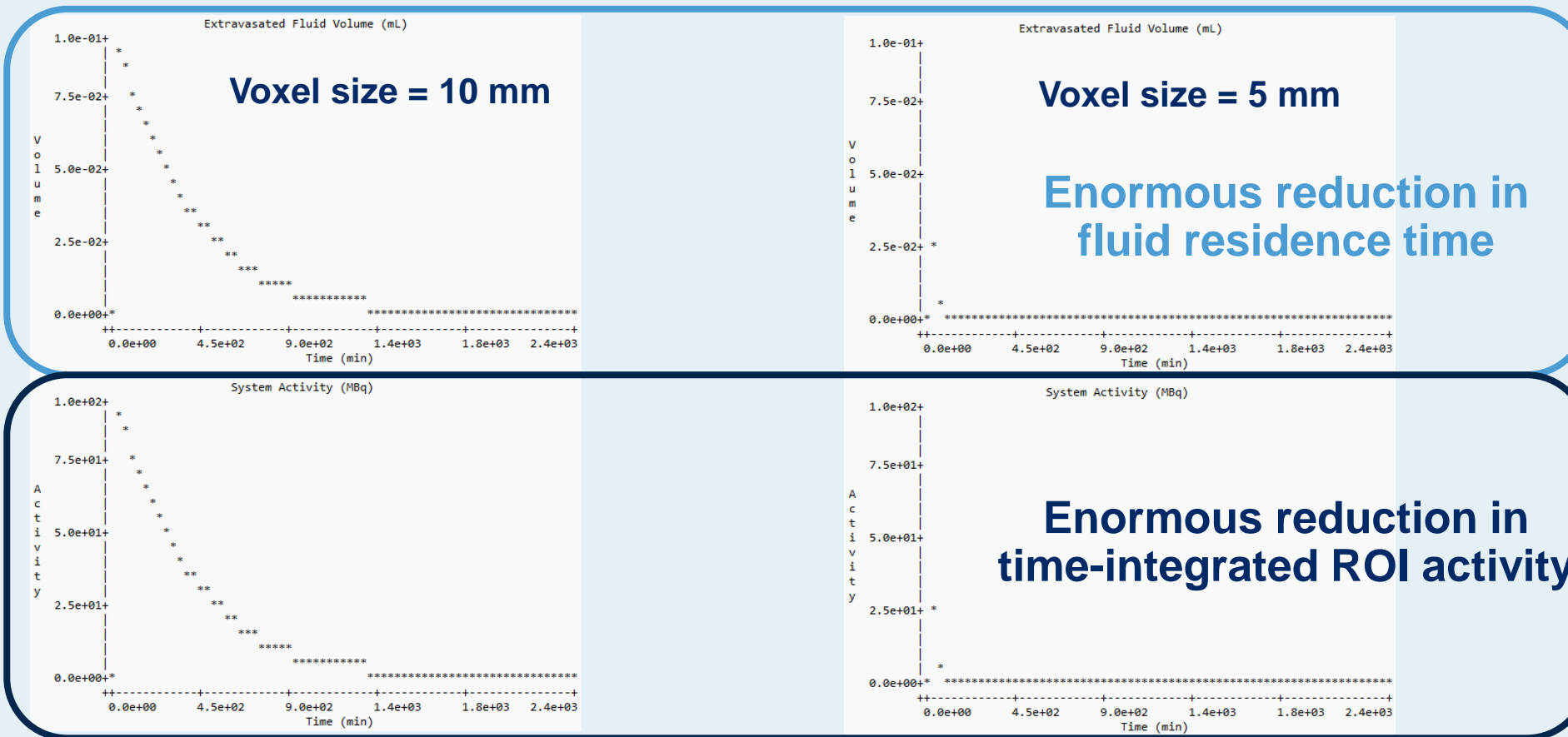
5. Voxel Size Effects

Voxel size effect on diffusion dominated test case



Simulation 1: Voxel Size = Effective Thickness

Simulation 2: Voxel Size = $\frac{1}{2}$ Effective Thickness



→ 2x reduction in voxel size

→ 7x reduction in clearance half-time

Simulation 1: Voxel Size = Effective Thickness			Simulation 2: Voxel Size = 1/2 Effective Thickness		
Outputs			Outputs		
Max Voxel Dose:	1.46e+00	Gy	Max Voxel Dose:	8.47e-01	Gy
Max Voxel Dose Rate:	1.80e-04	Gy/s	Max Voxel Dose Rate:	7.20e-04	Gy/s
Time to Max Voxel Dose Rate:	1.0	min	Time to Max Voxel Dose Rate:	1.0	min
ROI Exceeding Dose Threshold:	0.0	%	ROI Exceeding Dose Threshold:	0.0	%
Dose to ROI:	1.26e-01	Gy	Dose to ROI:	8.84e-03	Gy
Region Volume:	128.0	cm ³	Region Volume:	128.0	cm ³

2x reduction

14x reduction

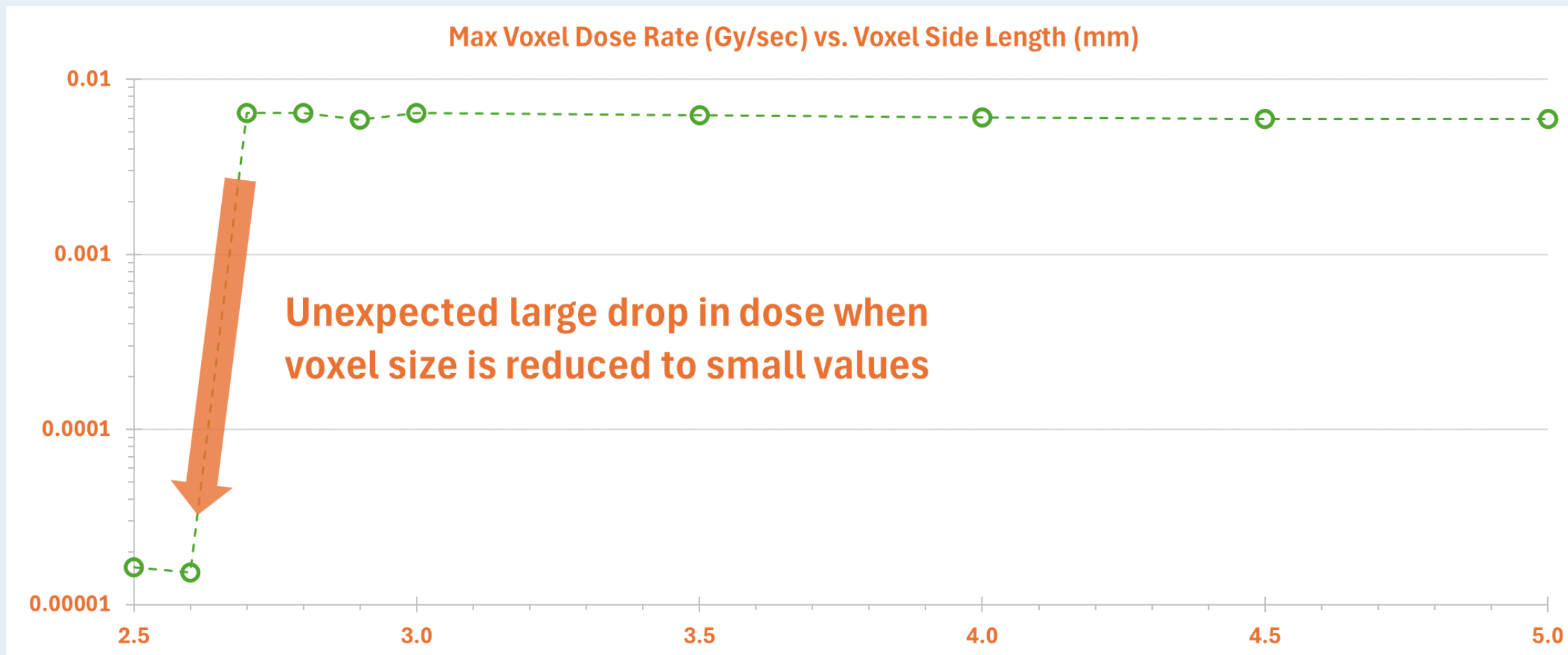


Examine voxel size effects on dose



30-min ^{177}Lu extravasation

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



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](#)
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ExtravDose Edit 🔗 ⋮

Last edited by Jeffrey Luitjens 1 month ago

Welcome

Welcome to the landing page for ExtravDose.

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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.

About

Extravasation Dose (ExtravDose) is a module added to V+ in version 2.0 for calculating local tissue dose from radiopharmaceutical extravasation during medical administration. The developed extravasation dosimetry model is a time-dependent, multi-dimensional, and multi-physics simulation that breaks the region into mesh/voxel volumes for analysis. It simulates the injection of a fluid with a defined activity concentration that is then transported throughout a region while accounting for mixing (i.e., concentration changes). With the transport of the concentrated fluid, a subsequent calculation of the spatial dependent dose rates and accumulated doses to tissue resulting from the fluid transport is determined. Models have been developed with the goal of focusing on ease of use for the end user in terms of the minimal number of required inputs while ensuring a reliable solution is obtained to help inform the decision-making process. Users can perform quick approximations based on a minimal number of basic inputs (Basic mode) or in-depth assessments utilizing advanced modeling features with an expanded set of input parameters (Advanced mode).

ed Extravasation Dosimetry v1.0

File Mode Help

ed V+ Extravasation Dosimetry v1.0
MODEL INPUTS

RCD

On this page

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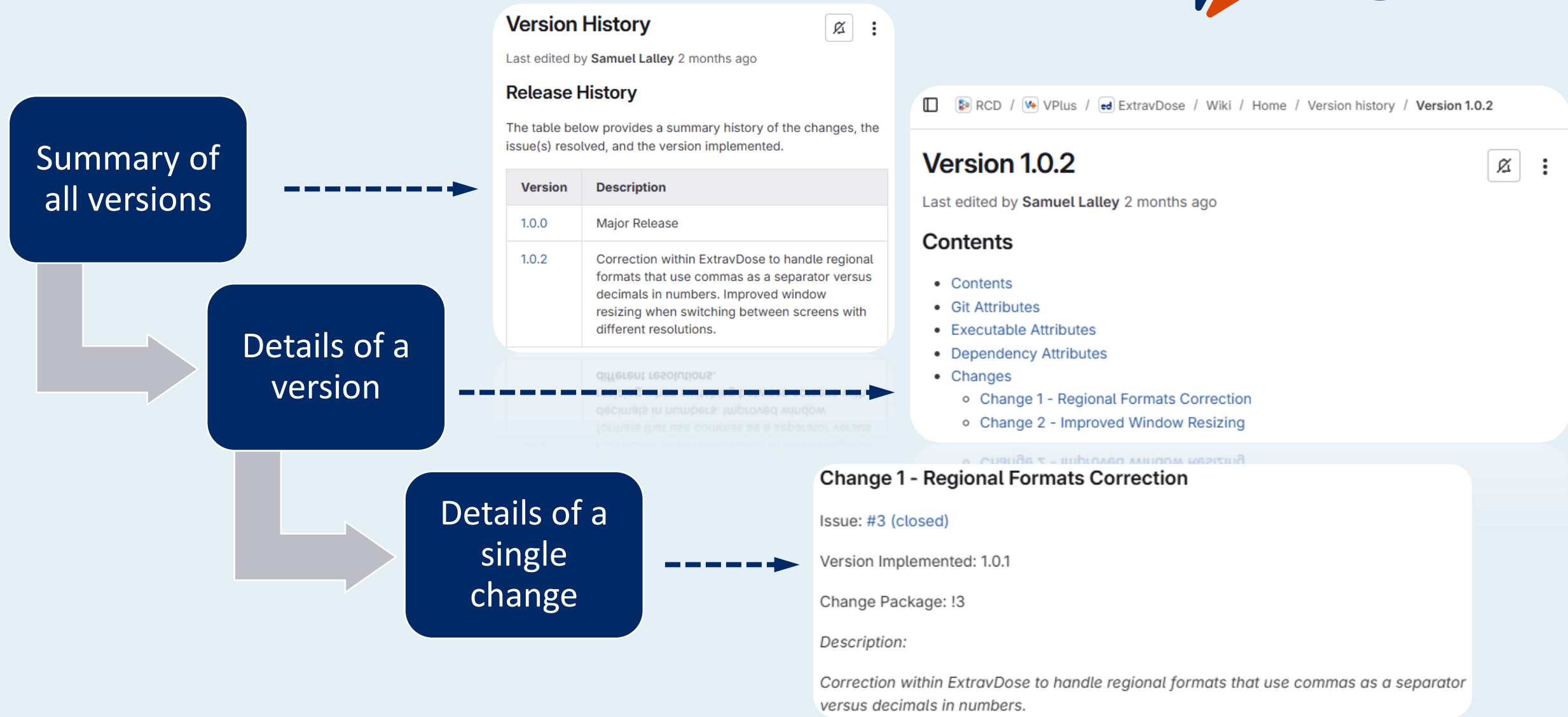
ExtravDose

- Discussion Board
- Frequently Asked Questi...
- Version History
- Version 1.0
- Version 1.0.2

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Version History – Levels of Detail



FAQs and Discussion Boards



RCD / VPlus / ExtravDose / Wiki / Home / Frequently Asked Questions

Frequently Asked Questions

Last edited by Jeffrey Luitjens 2 months ago

A set of frequently asked questions related to ExtravDose.

- 1. What is an extravasation as related to the NRC medical definition?
- 2. Why did NRC support development the extravasation model?
- 3. I normally use two monitors with different resolution settings. Will the ExtravDose module accommodate these settings.
- 4. In BASIC mode, how do I change the value of Pixel Side Length?
- 5. Dose the new NRC's extravasation model estimate dose from alpha-particle emissions?
- 6. Dose the extravasation model handle decay progeny?

RCD / VPlus / ExtravDose / Wiki / Home / Discussion Board

Discussion Board

Last edited by Samuel Lalley 3 months ago

This is an environment to host active discussion between users.

Oldest first

Preview | B I | | + v

Write a comment or drag your files here...

Switch to rich text editing

Make this an internal note

Comment

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



Viewing Issues



RCD / VPlus / ExtravDose / Issues

New issue

Open 7 Closed 2 All 9

Search or filter results... Created date

- Display Project Dependencies in About Window
#10 · created 1 month ago by Samuel Lalley
status In Development type No User Impact
- Dosimetry results displayed
#9 · created 2 months ago by Samuel Lalley
type Feature
- Effective Tissue Thickness Units change when switching from basic to advanced mode
#8 · created 2 months ago by Samuel Lalley
status Awaiting Evaluation type Model Error
- Dates/times for the Events in the Timeline
#7 · created 2 months ago by Samuel Lalley
status Awaiting Evaluation type Model Error
- ExtravDose Progeny Inclusion
#6 · created 2 months ago by Samuel Lalley
type Feature
- Event Table Keyboard Trap
#5 · created 2 months ago by Samuel Lalley
Accessibility status Awaiting Evaluation type Documentation
- Results Window Run Time**
#4 · created 2 months ago by Samuel Lalley
status Awaiting Evaluation type UI Error

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

extravdose#4

Results Window Run Time

Open Issue created 2 months ago by Samuel Lalley

Description

The results window allows the user to jump to a specified time. When running the default case, if the user attempts to jump to 30 minutes the time is reset to 0.00 when it should jump to 30.03 minutes (the last timestep).

Version

1.0

Attachments

None.

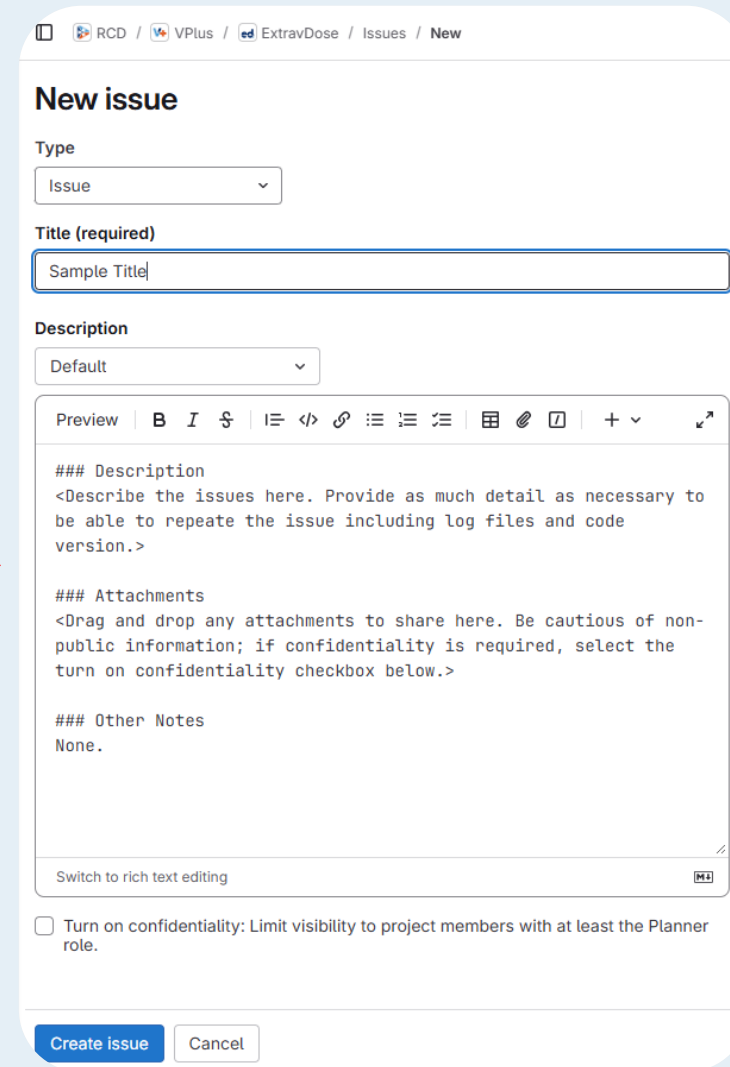
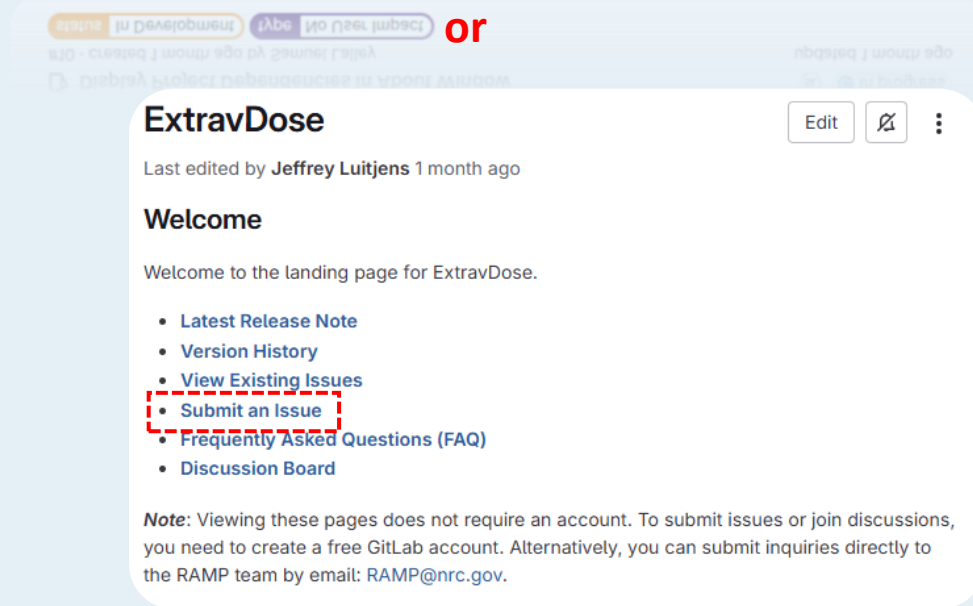
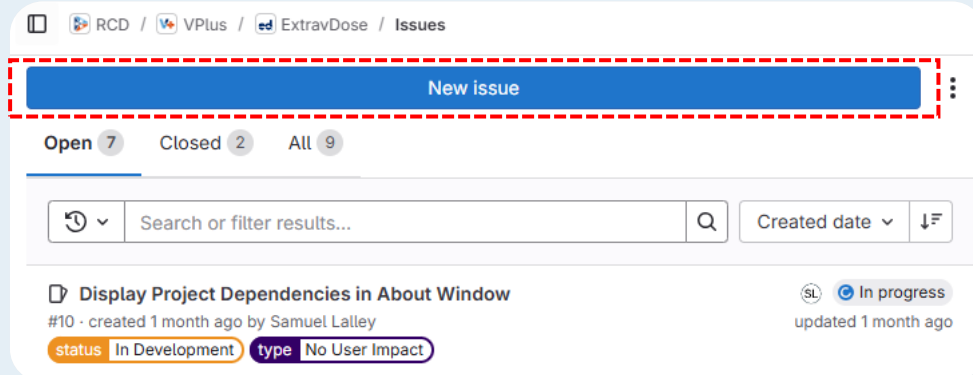
Other Notes

This issue is related to issue 127 of the internal issue tracker.

Status	To do
Assignees	None - assign yourself
Labels	Awaiting Evaluation x UI Error x
Parent	None
Weight	None



Submitting an Issue




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RCD / VPlus

VPlus 

V+ is a U.S. Nuclear Regulatory Commission (NRC) computer code used by staff members and NRC licen...
[Read more](#)

Subgroups and projects Shared projects Shared groups Inactive

-  **ed ExtravDose** 
Extravasation Dose (ExtravDose) calculates local tissue dose from radiopharmaceutical extravasation d...
-  **EyeDose** 
EyeDose allows for the evaluation of photon and electron dose to the lens of the human eye for radionu...
-  **NeutronDose** 
NeutronDose estimates shallow tissue dose at a user-specified depth following exposure to a source of...
-  **RadToolbox** 
The Radiological Toolbox software (RadToolbox) provides access to physical, chemical, anatomical, ph...
-  **SkinDose** 
SkinDose calculates dose equivalent from photon, electron, and alpha radiation from more than 1,200 r...
-  **VPlus-Main** 
-  **WoundDose** 
WoundDose is based on National Council on Radiological Protection and Measurement (NCRP) Report ...



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



End of Intermediate Training