ACCELERATED PARTIAL BREAST IRRADIATION: INTERSTITIAL IMPLANTS

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Hypotheses Tested by Wide-Volume Breast Brachytherapy Concept

- The entire breast does not need to be irradiated in all patients
- Intensifying radiotherapy to the tissue at greatest risk for subclinical disease may reduce local recurrence rates

Prescription Dose

40-34 Gy in 8-10 fractions

twice daily over 4-5 days with BED of 45 Gy ($\alpha/\beta = 10$)

The UW Program

- From 11/2000 – 37/2005:

  Total of 280 patients have been treated with definitive wide volume breast brachytherapy.

  254 patients have been treated with interstitial brachytherapy.

  26 patients have been treated with mammosite (intracavitary).

Traditional Tools

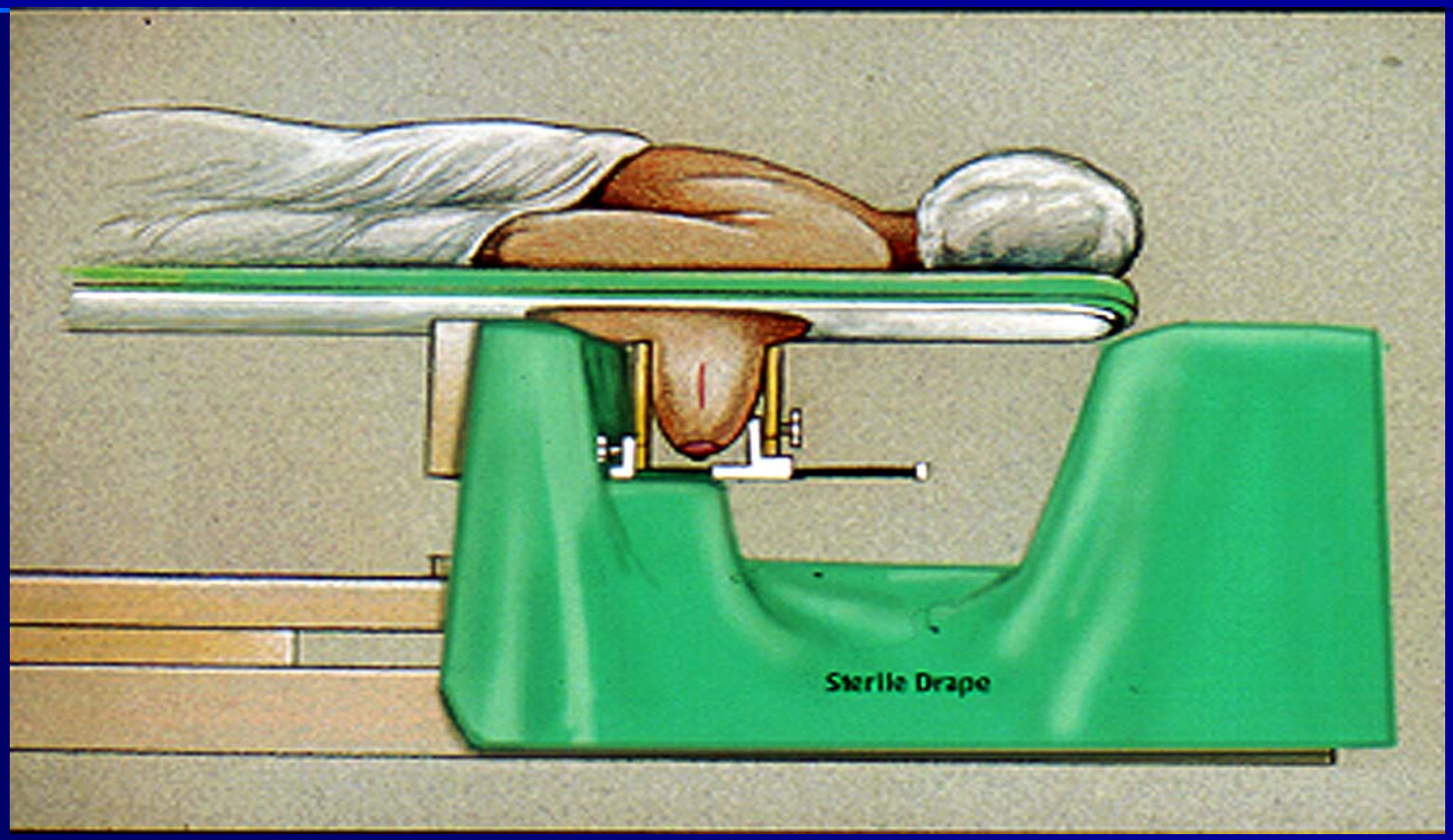
- Brachytherapy - Surgical Art - Prior knowledge of location and volume of target needed for implant

- Dosimetry based on orthogonal films for source localization incorporating very large random errors inherent in conventional treatment evaluation.

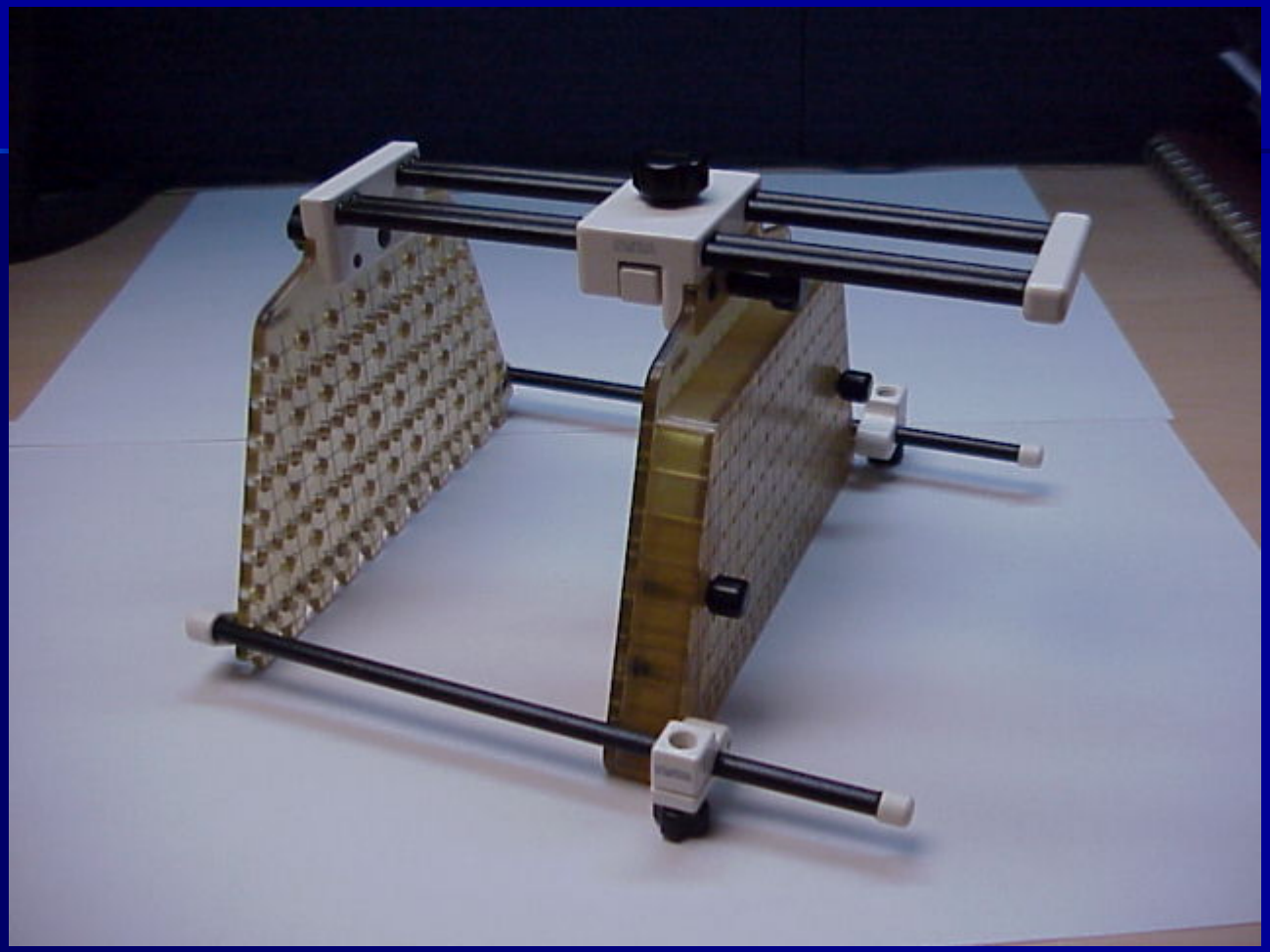
Applicator Placement Techniques

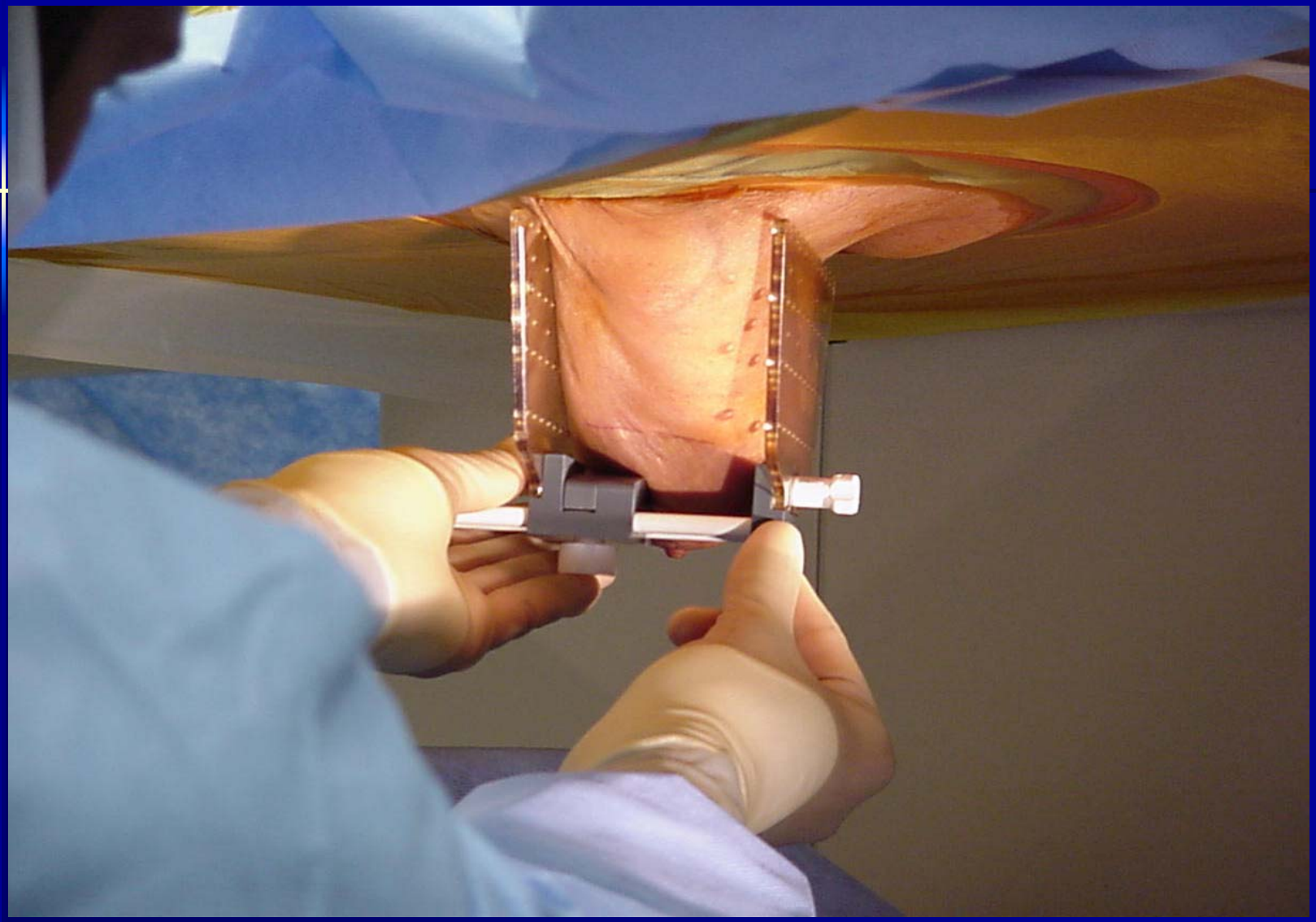
- Interstitial:
  - Template-guided prone approach; uses a stereotactic core biopsy table with digital mammographic guidance
  - Free-hand supine approach; uses ultrasound guidance

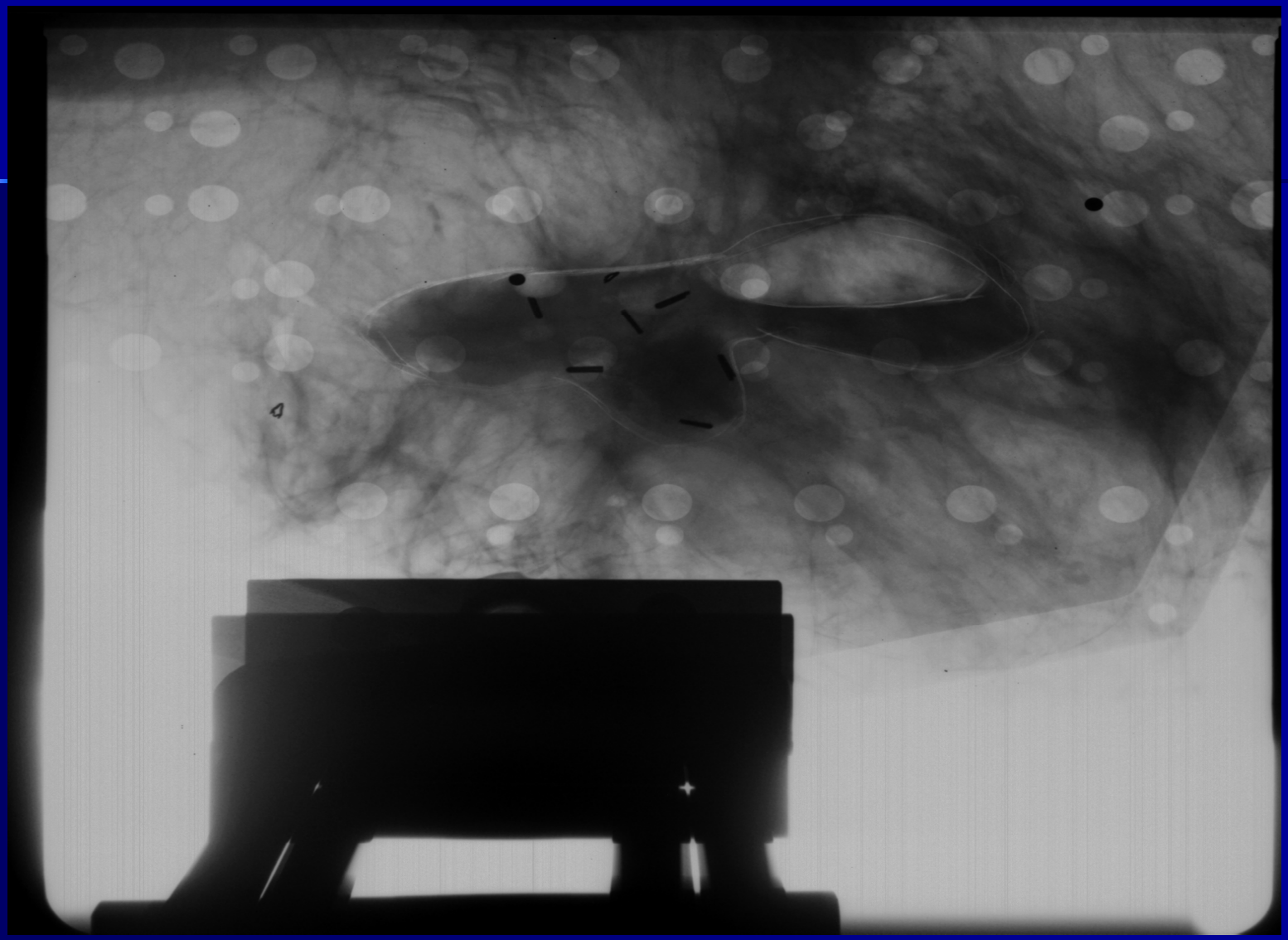
Prone Patient Position



Template-guided prone approach





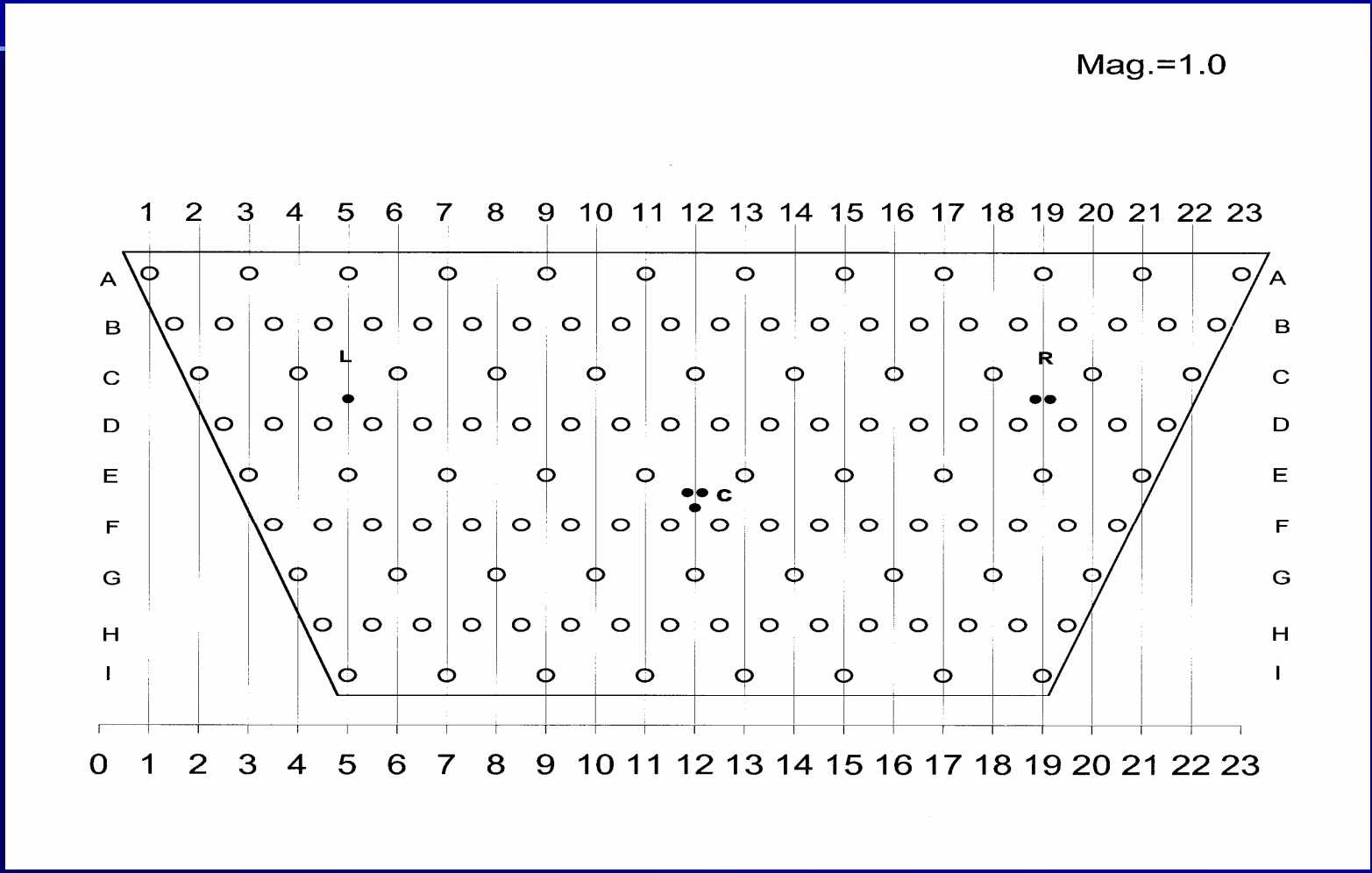


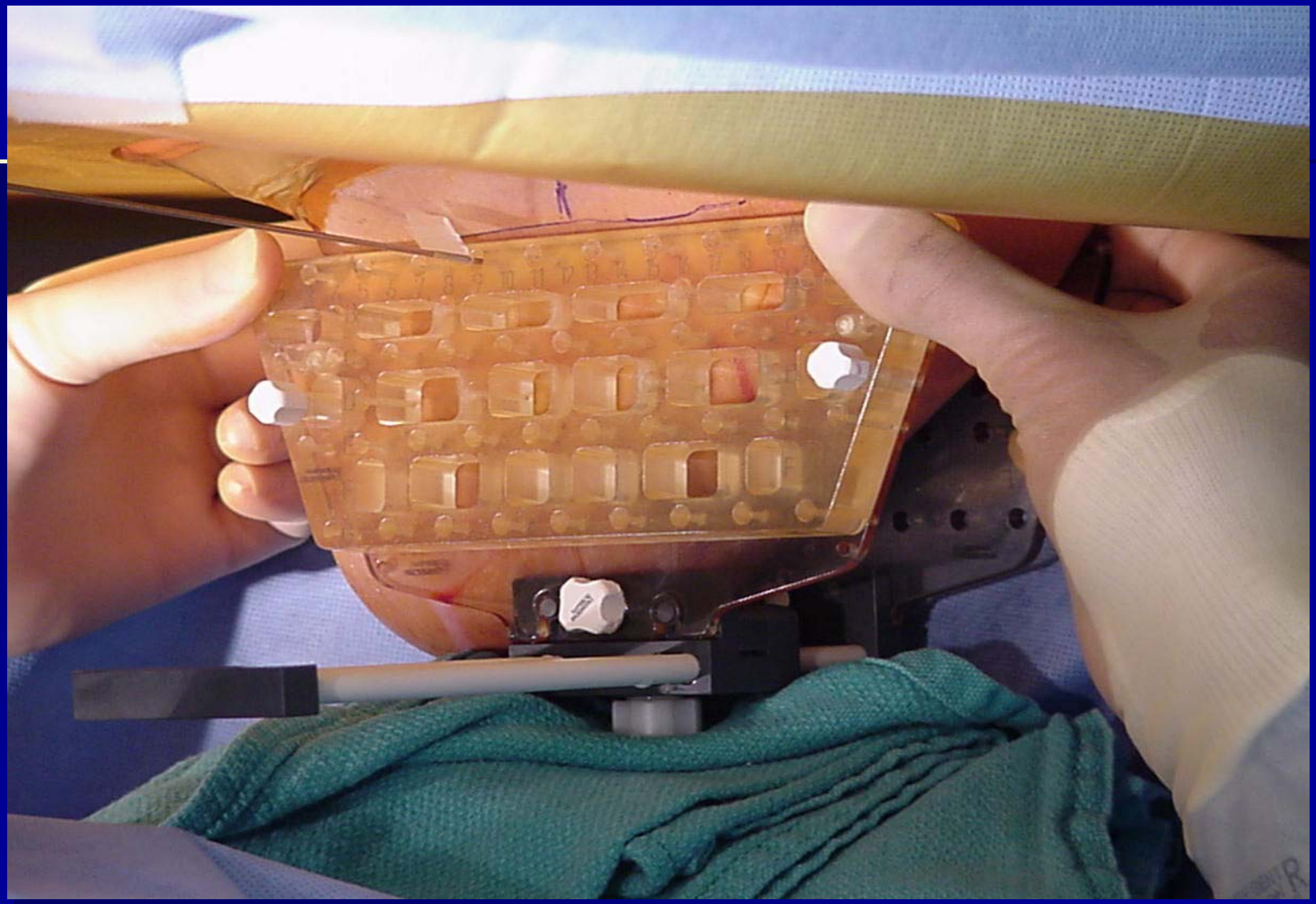
Target Volume Definition

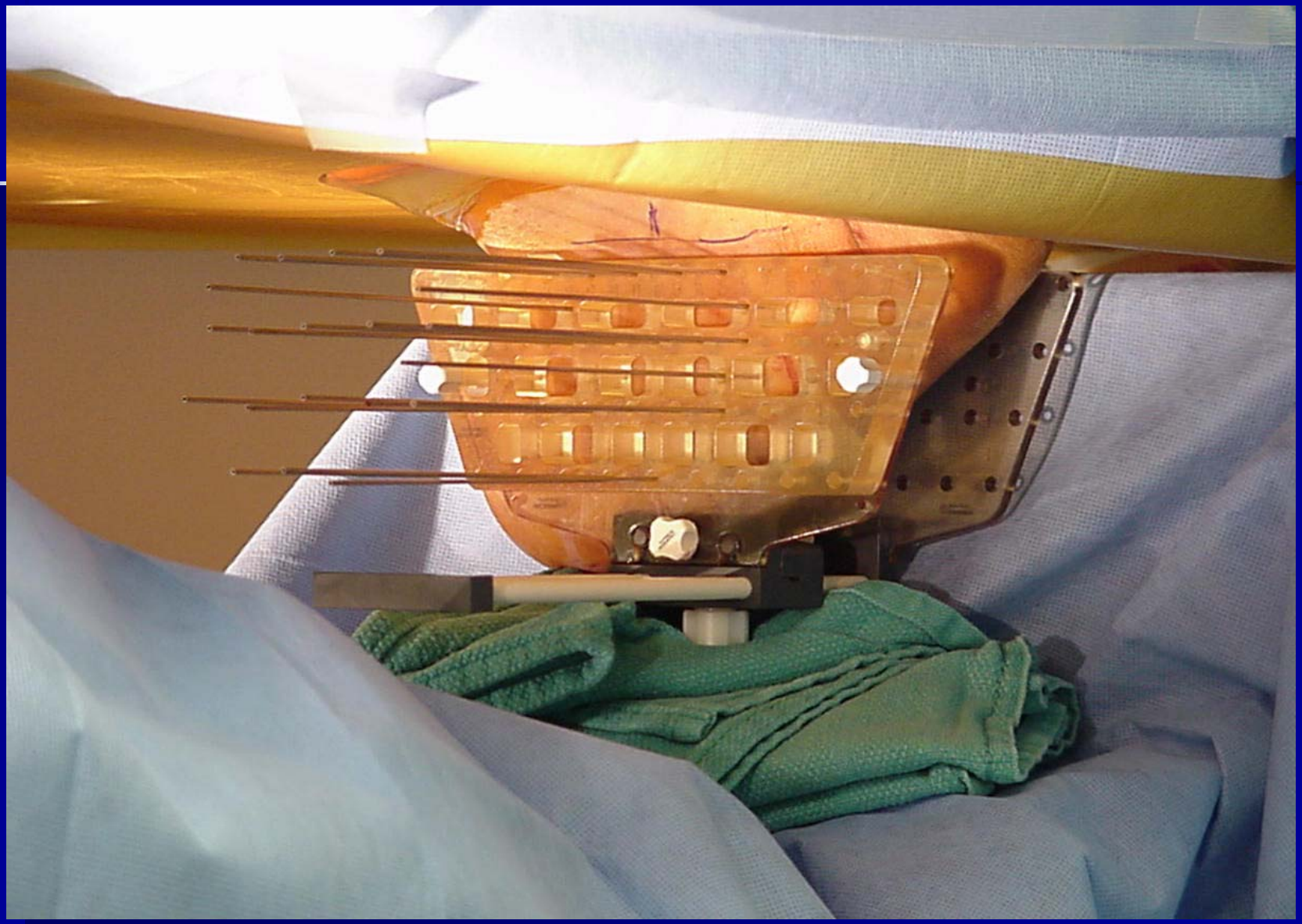
Target Volume

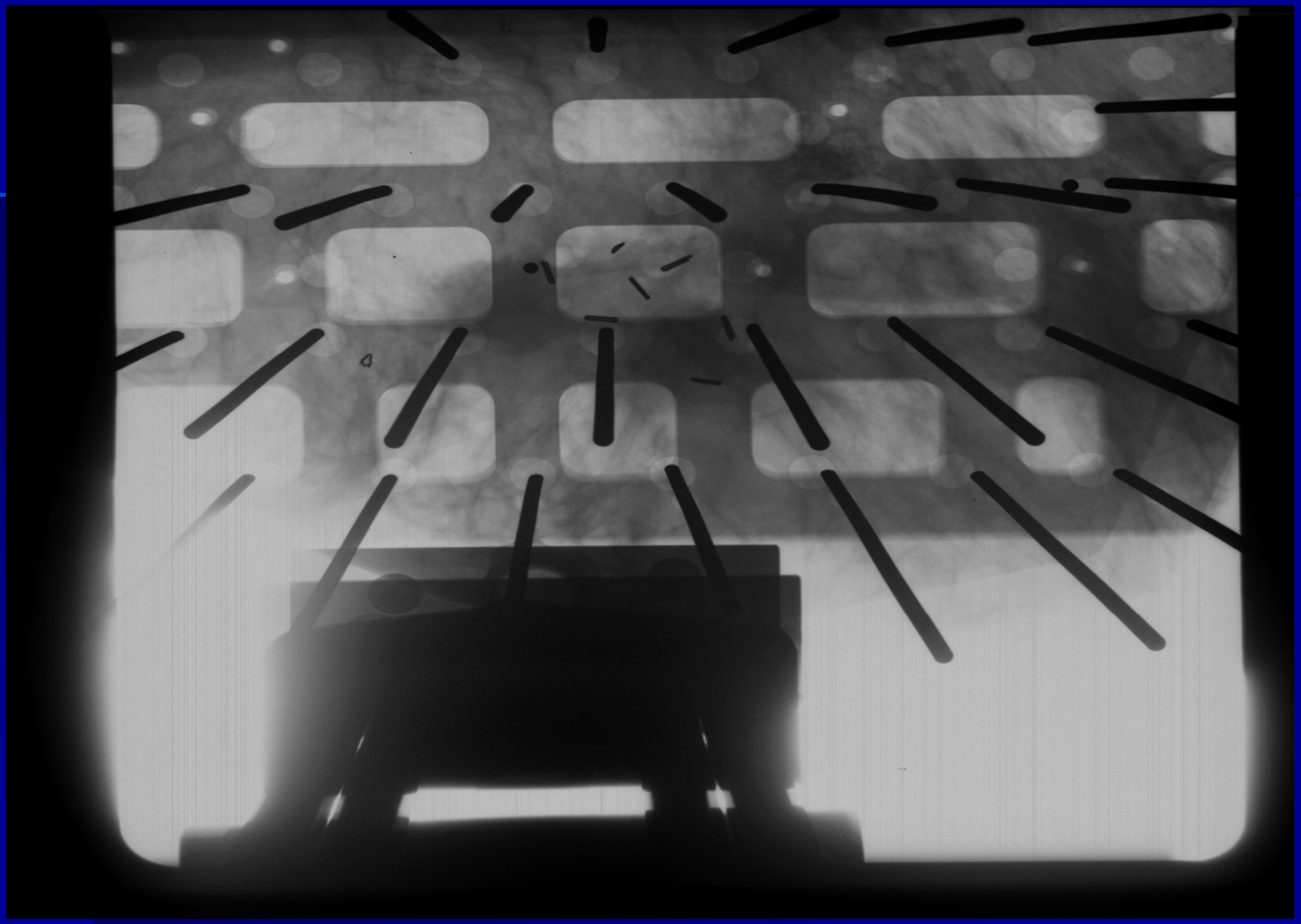
Lumpectomy cavity/surgical clips + 2-cm margin

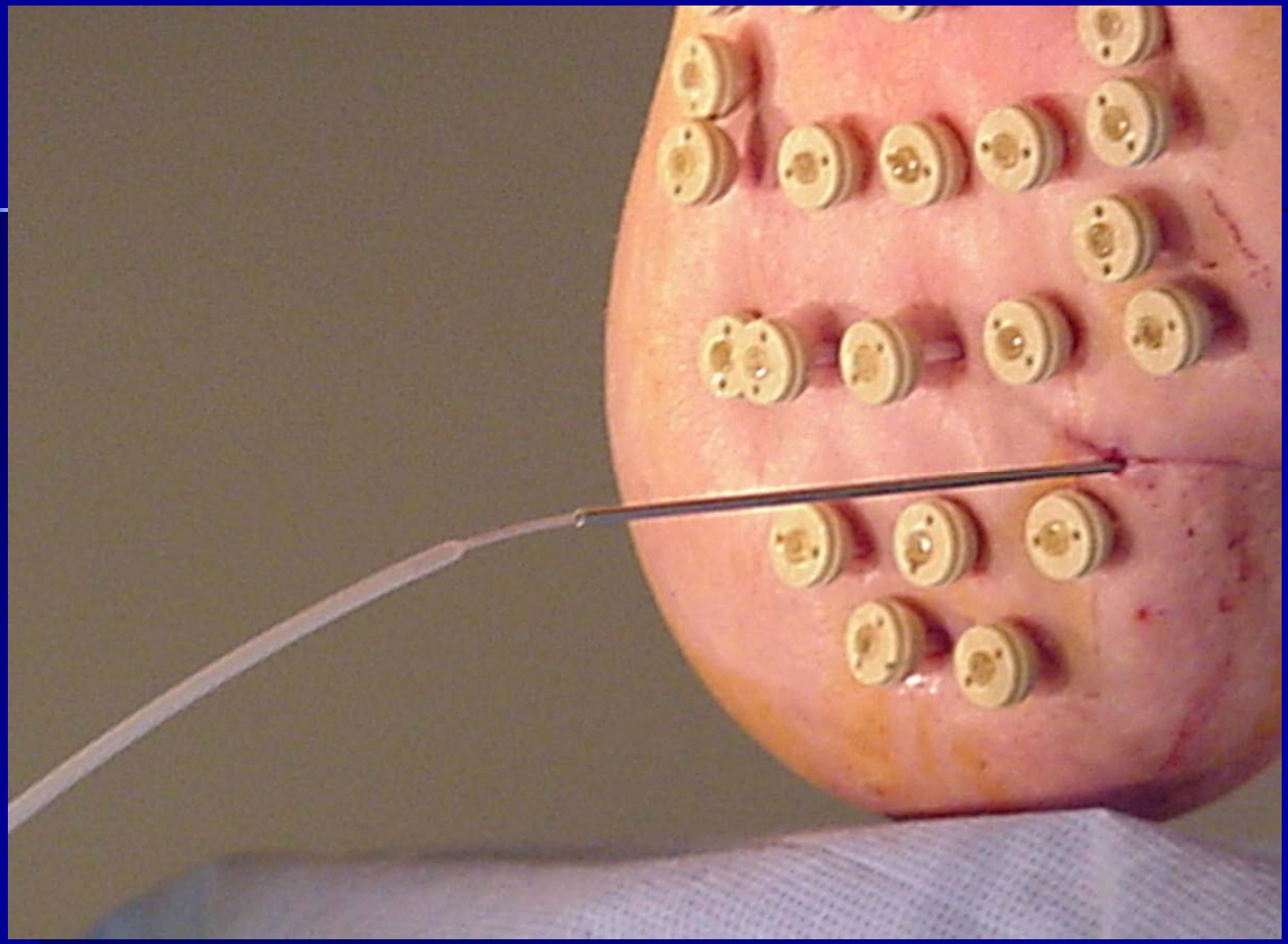
Schematics of Template

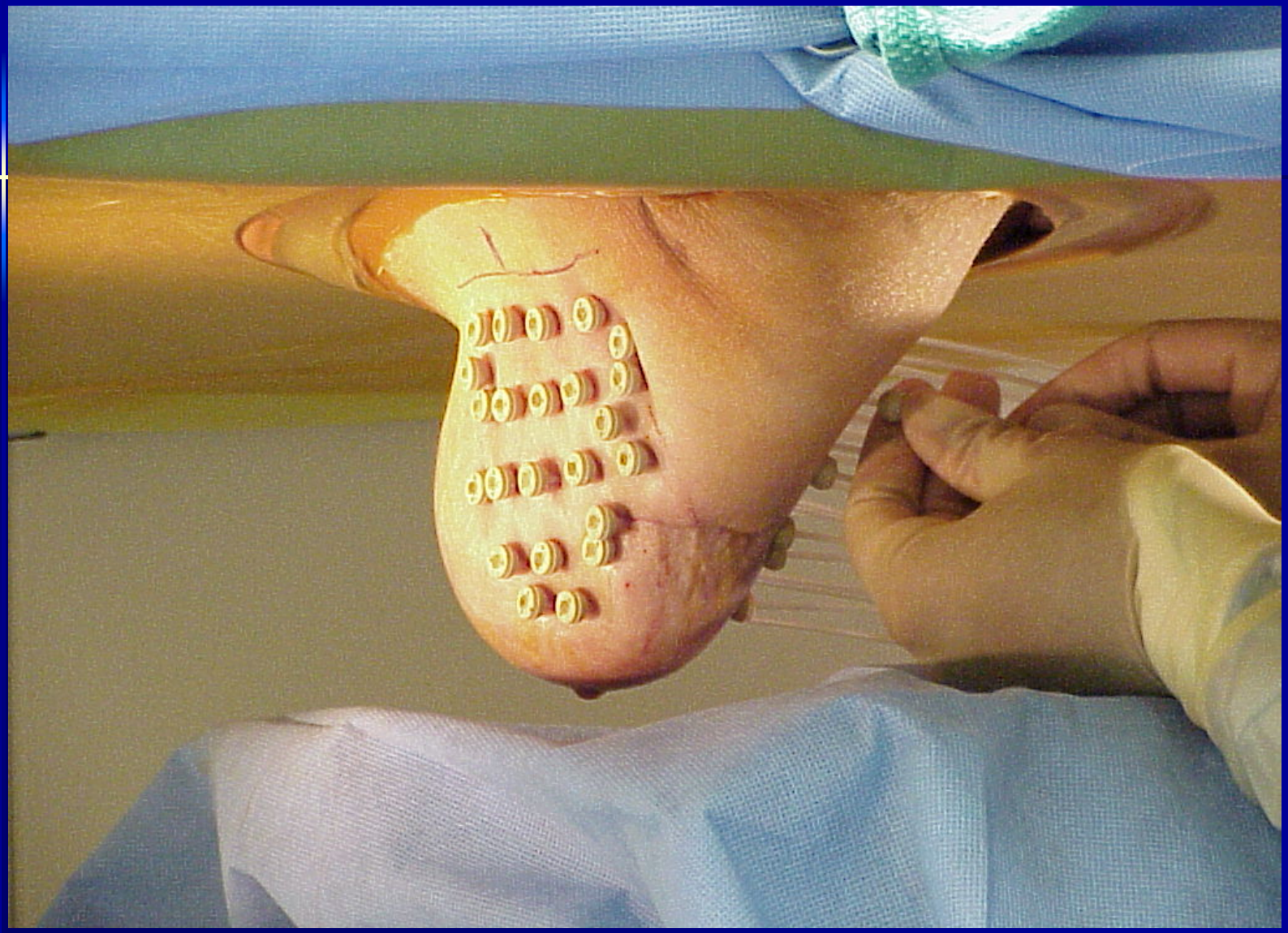




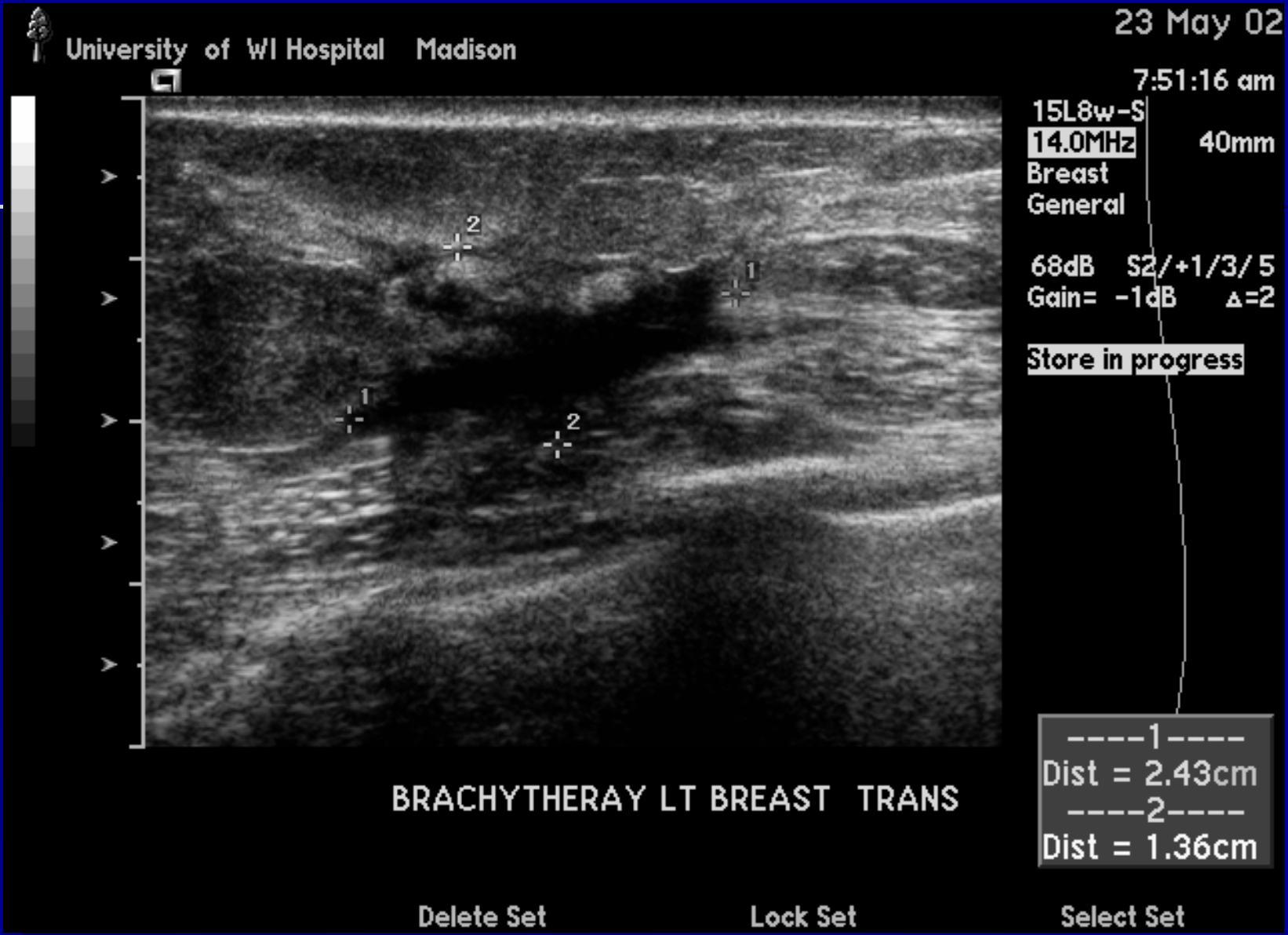








Free-hand supine approach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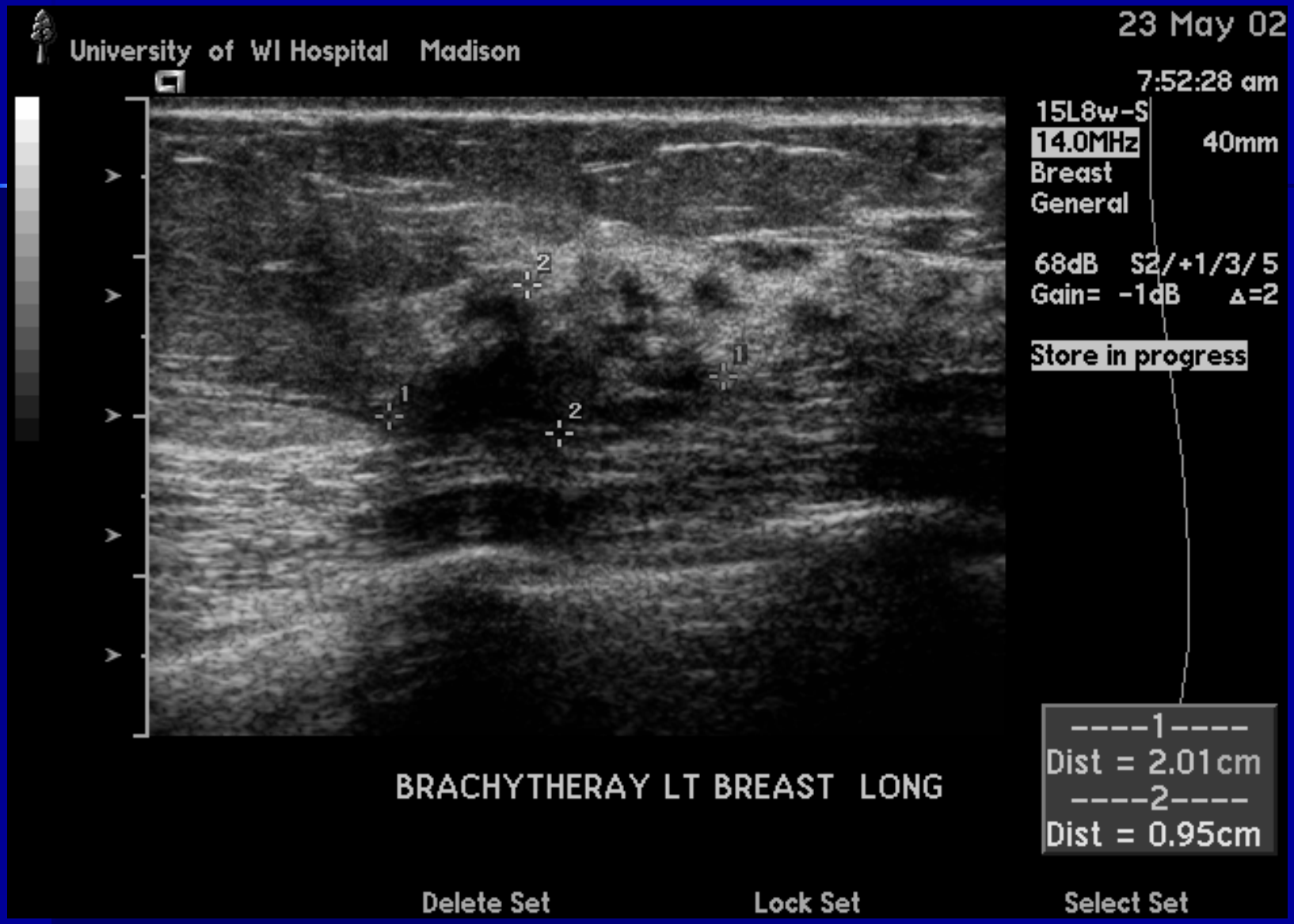
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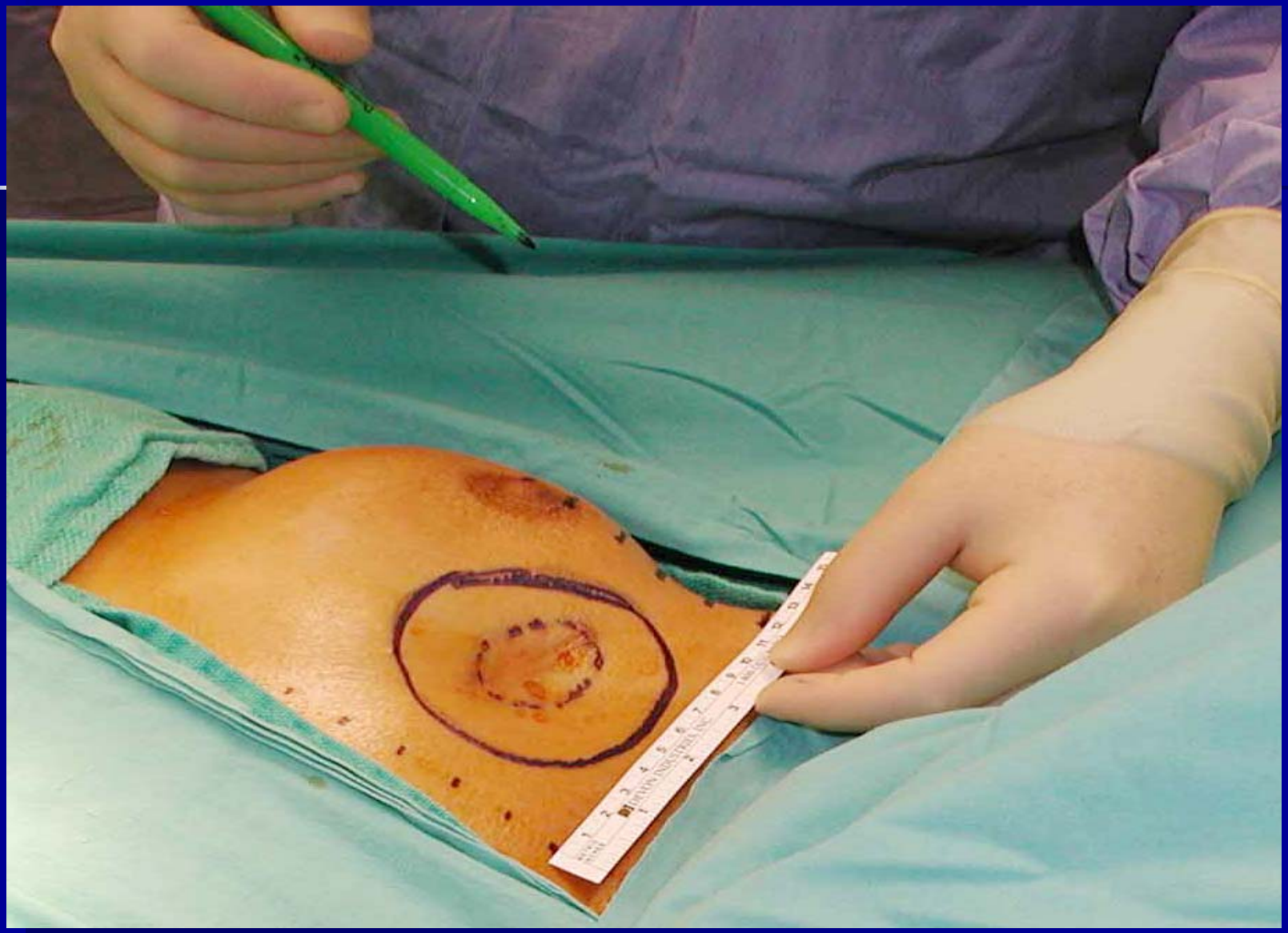

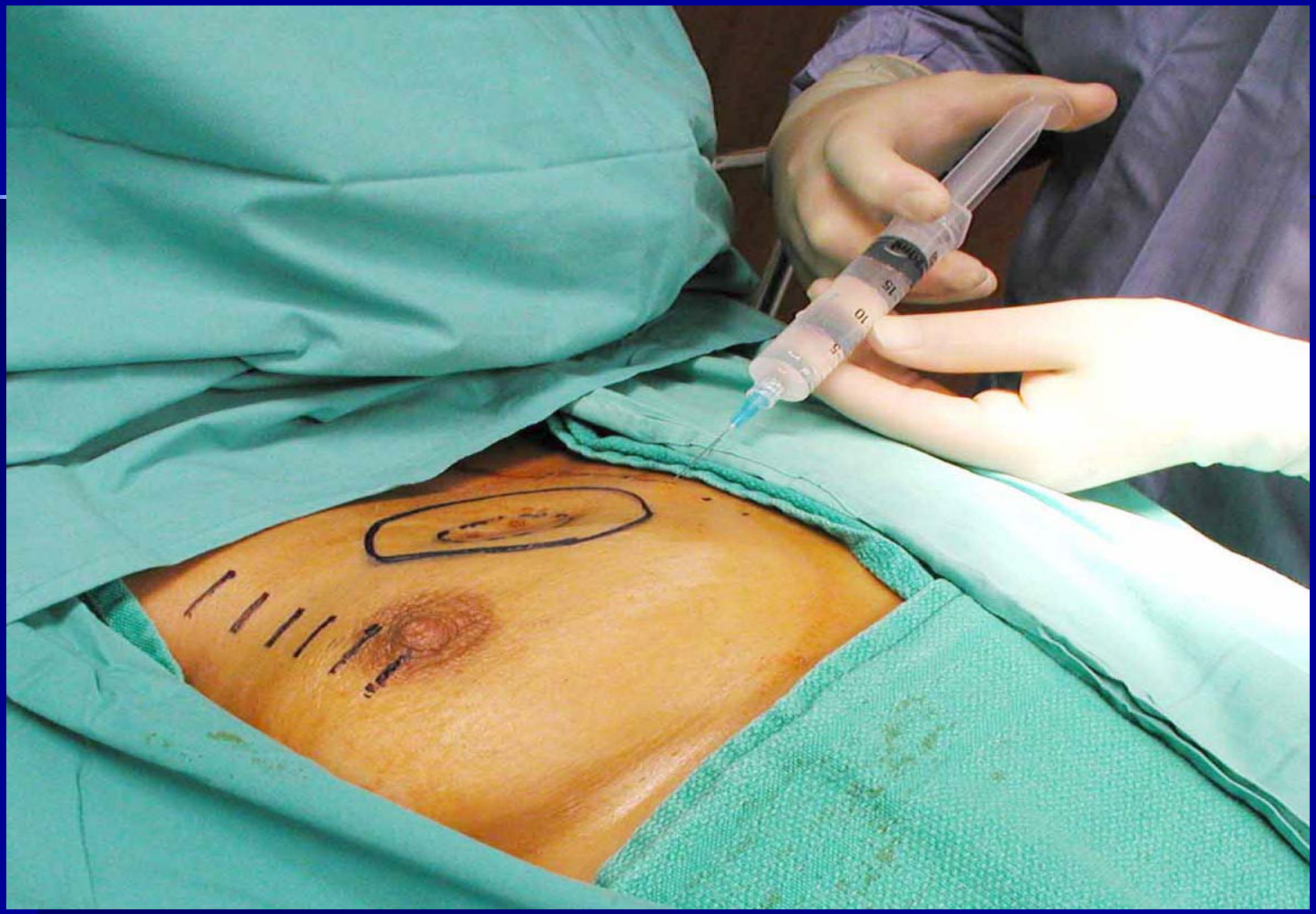

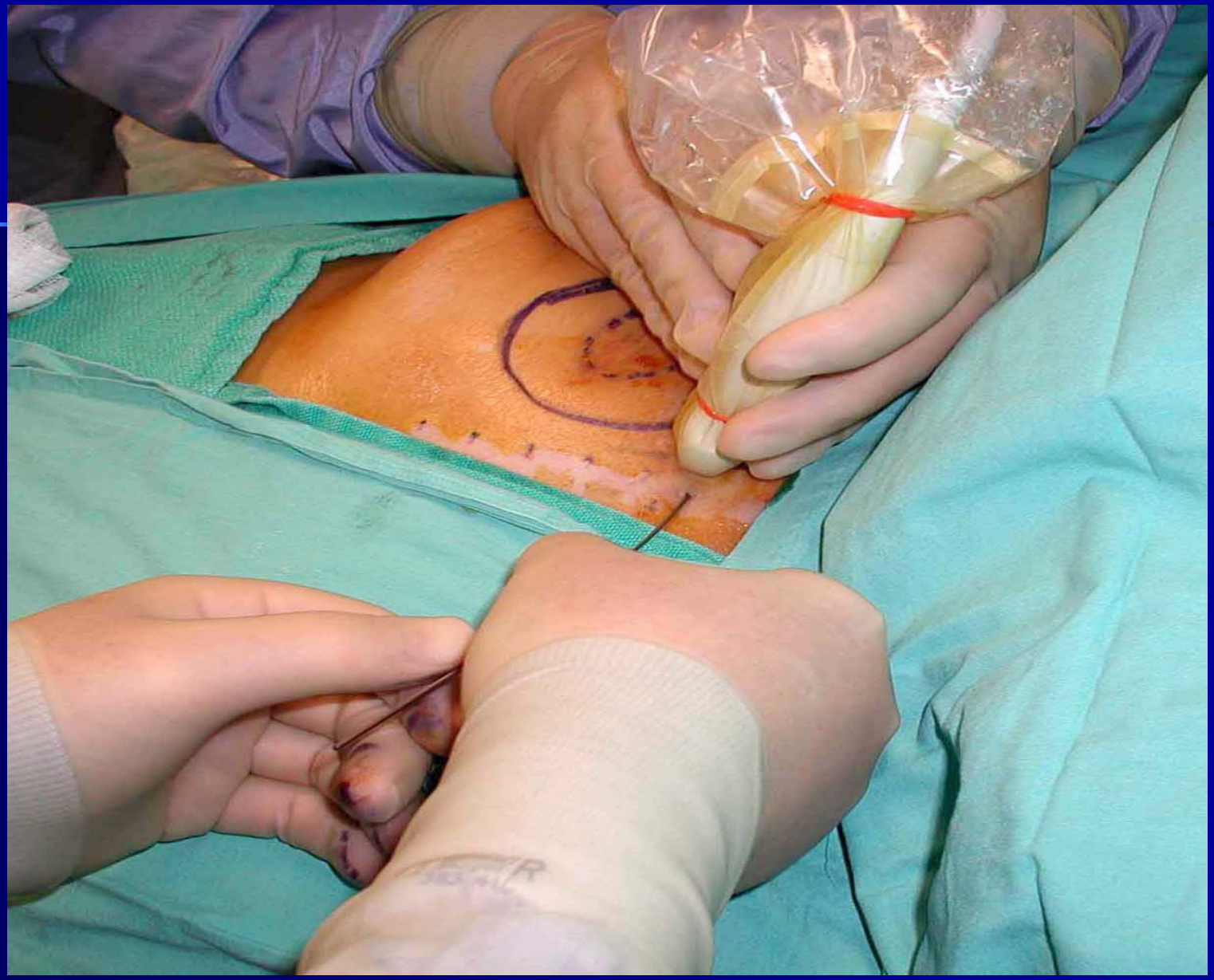

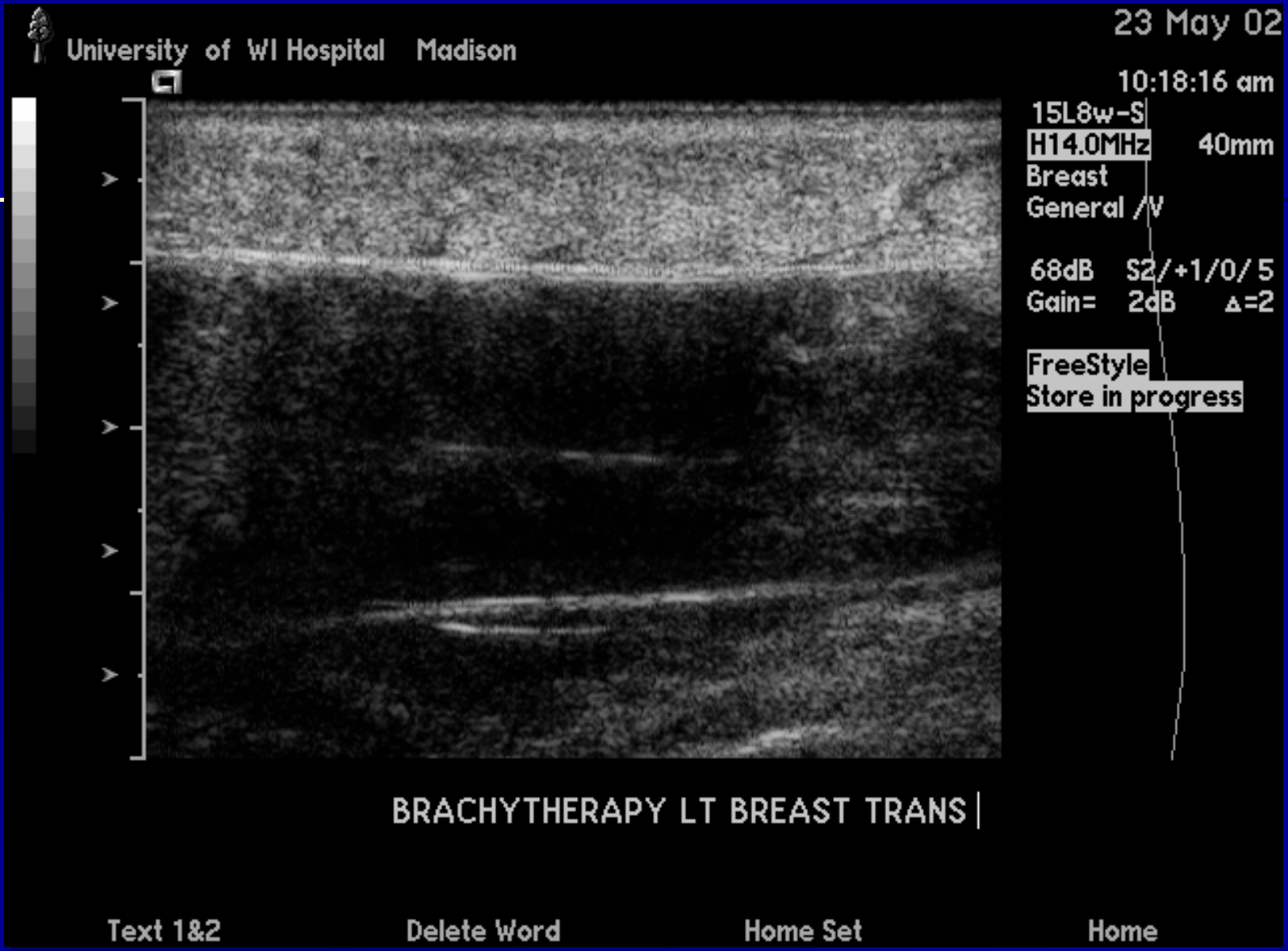
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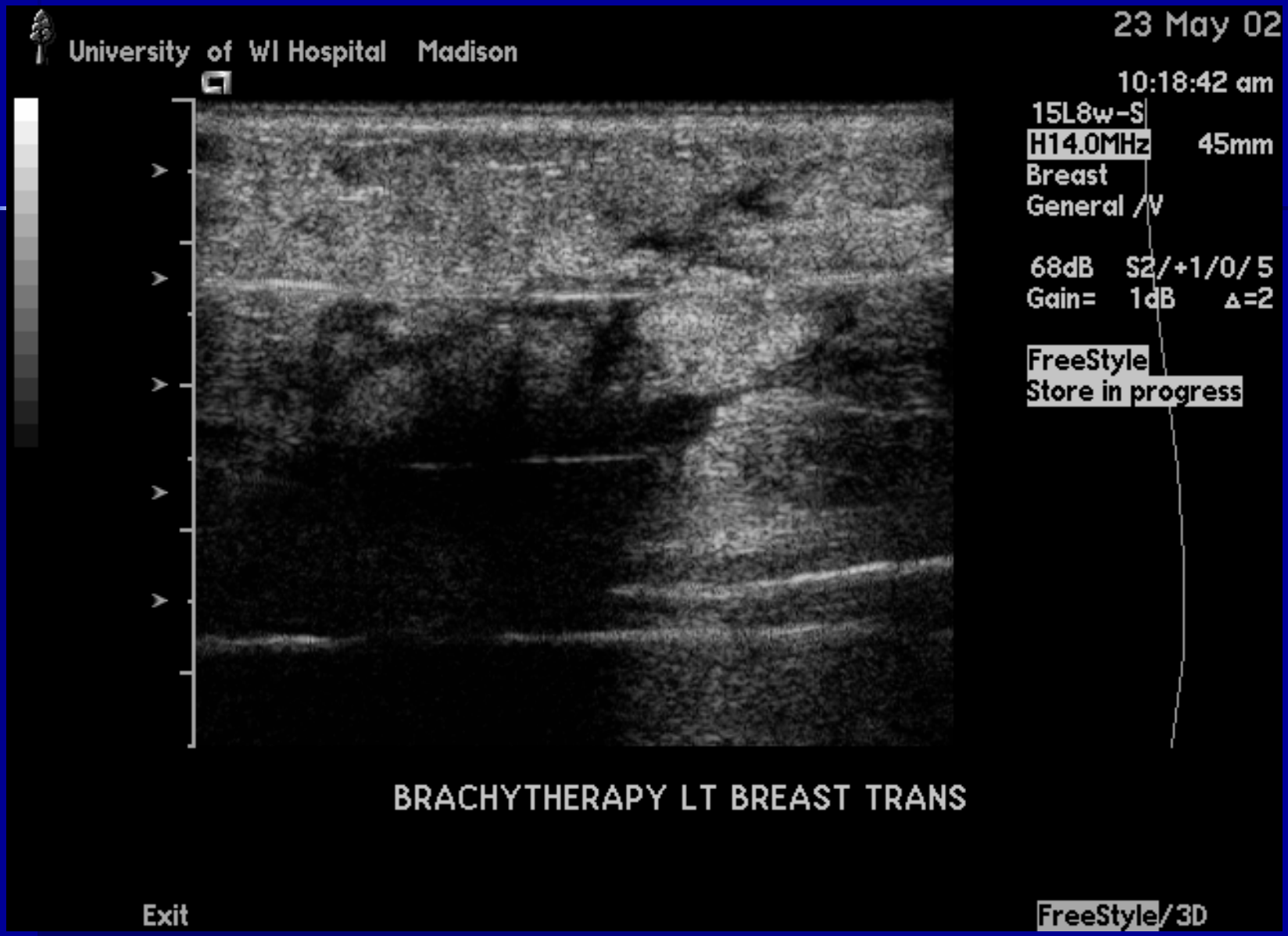
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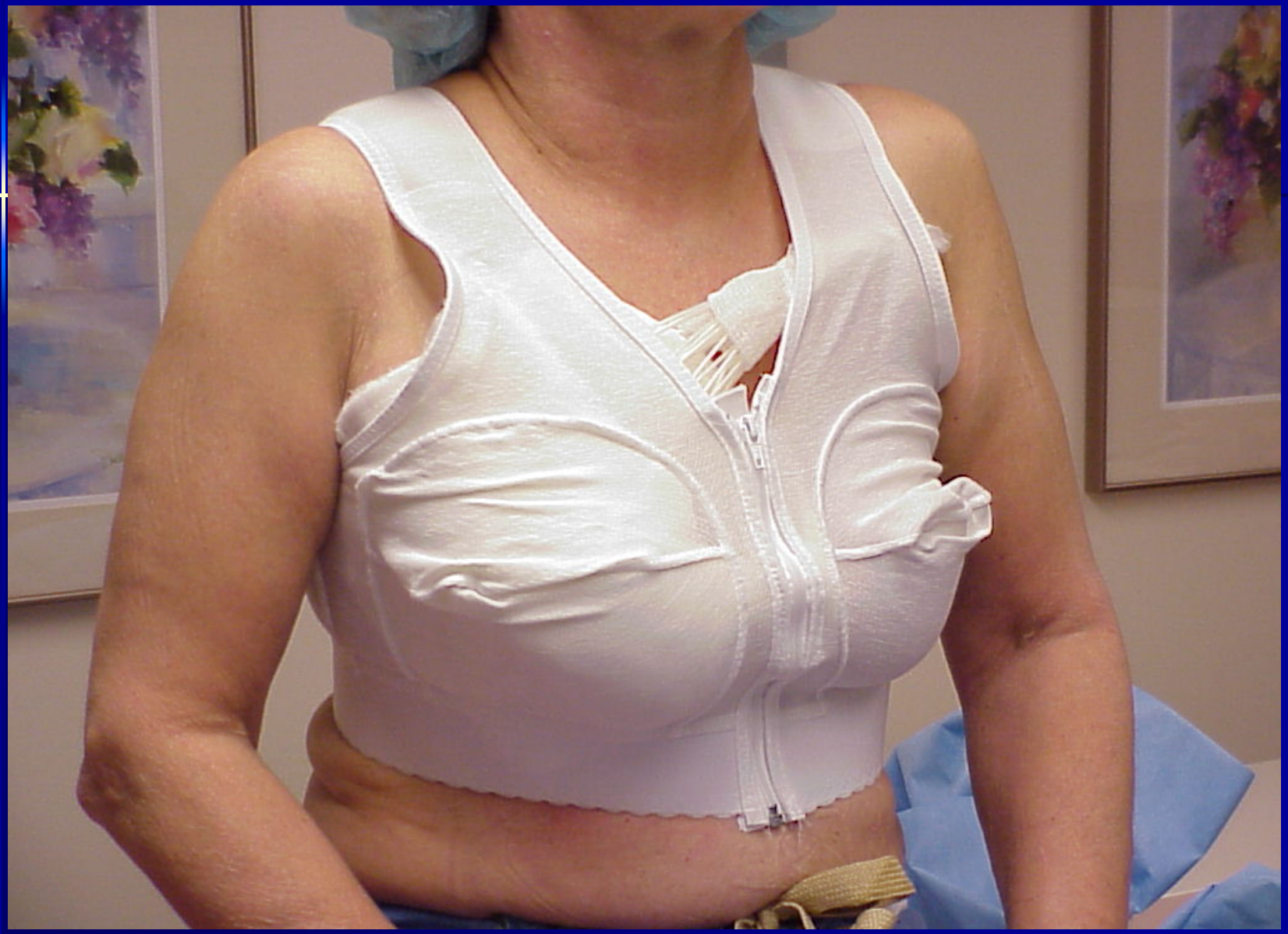
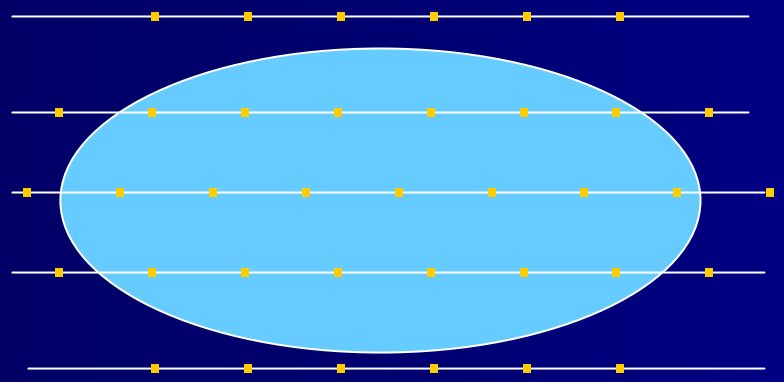


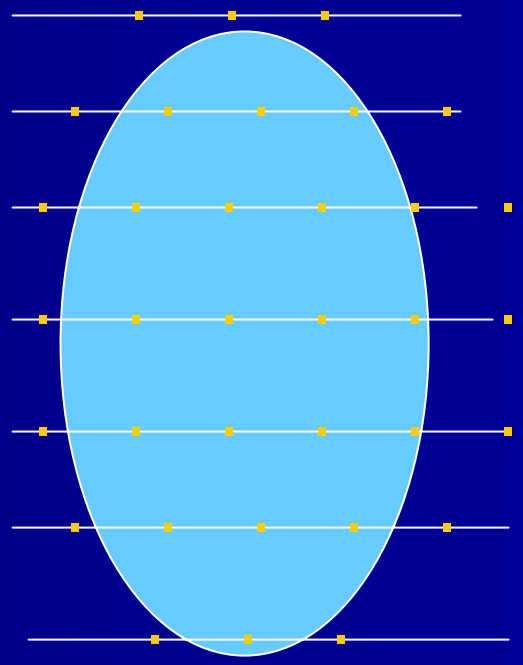
Comparison of Techniques

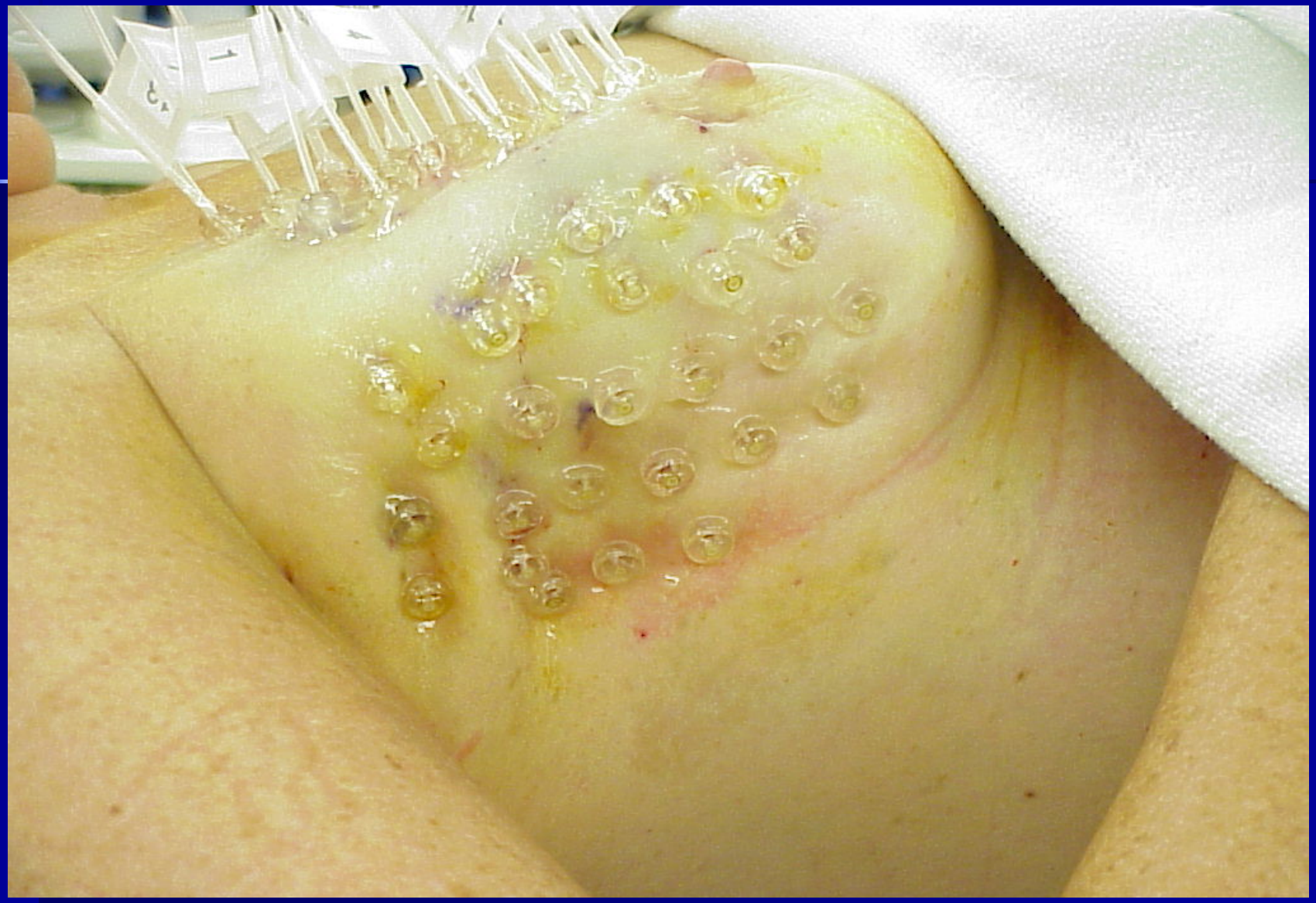
Supine/Ultrasound	Prone/Digital Mammogram
Surgical Art Operator Dependent	Template/Operator Independent
Less Number of Catheters	More Number of Catheters
Irradiation Time Same	Irradiation Time Same
Less Simulation/Planning Time	More Simulation/Planning Time
Less Treatment Time	More Treatment Time

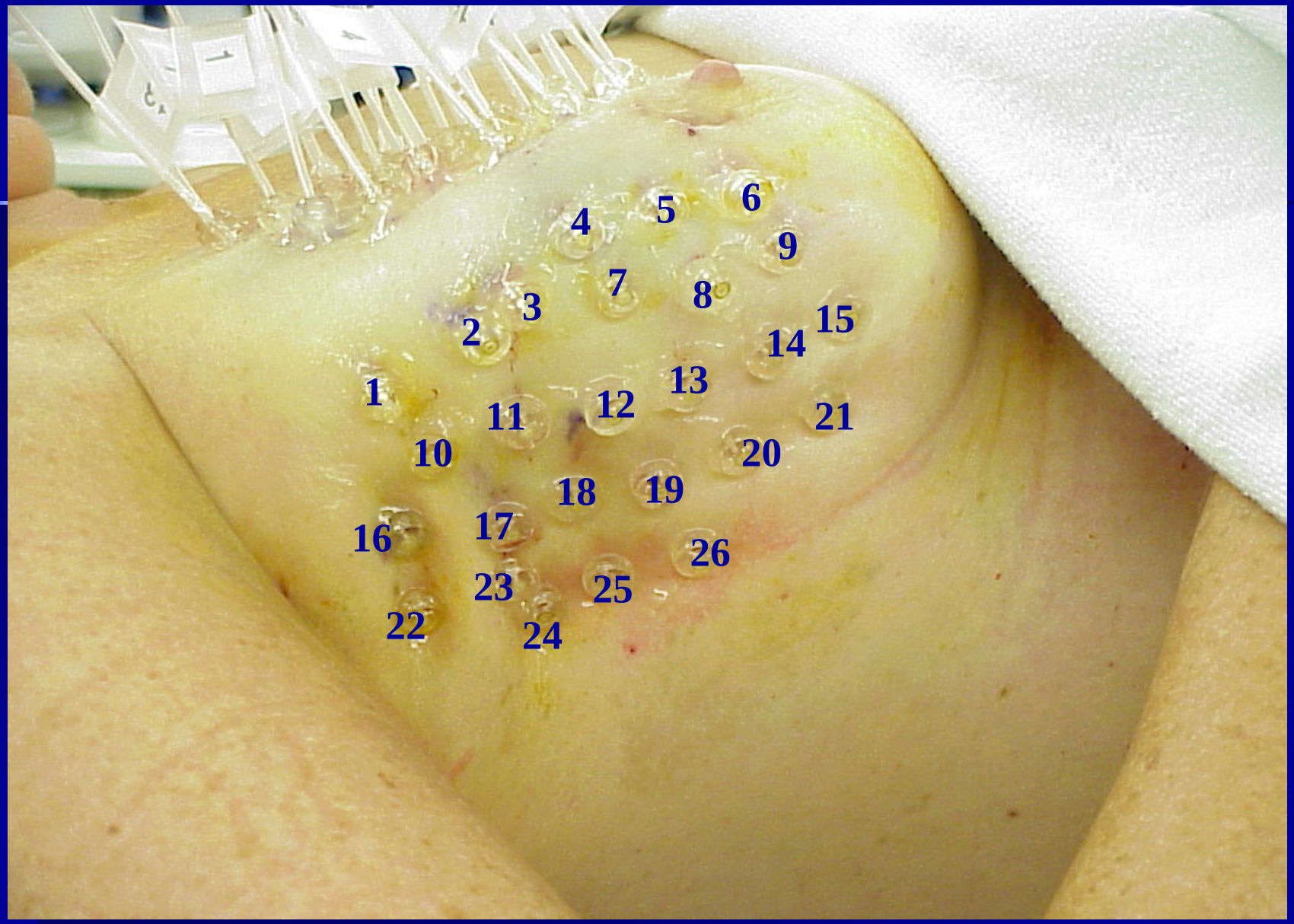
- Patient Supine



- Patient Prone



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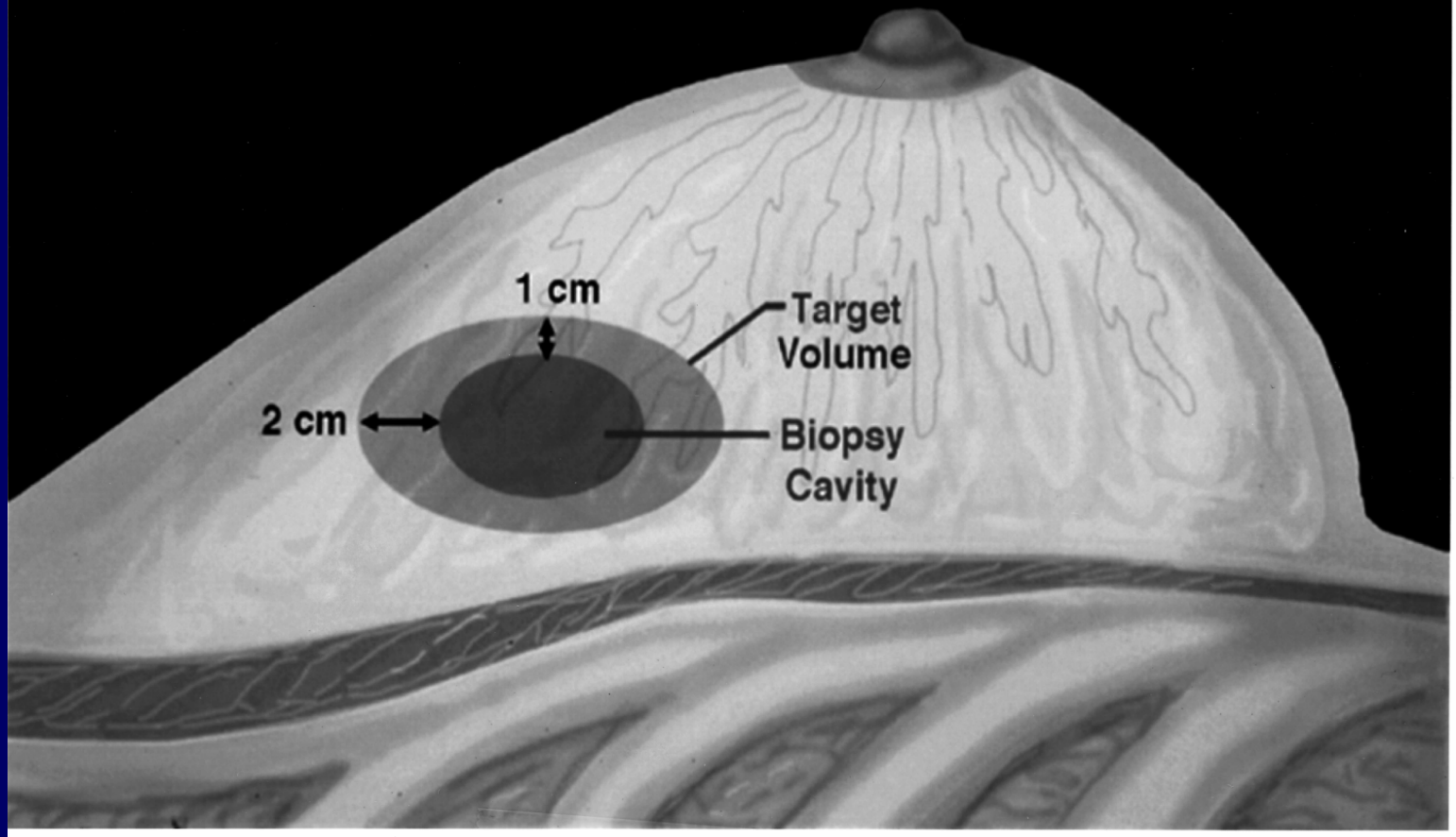
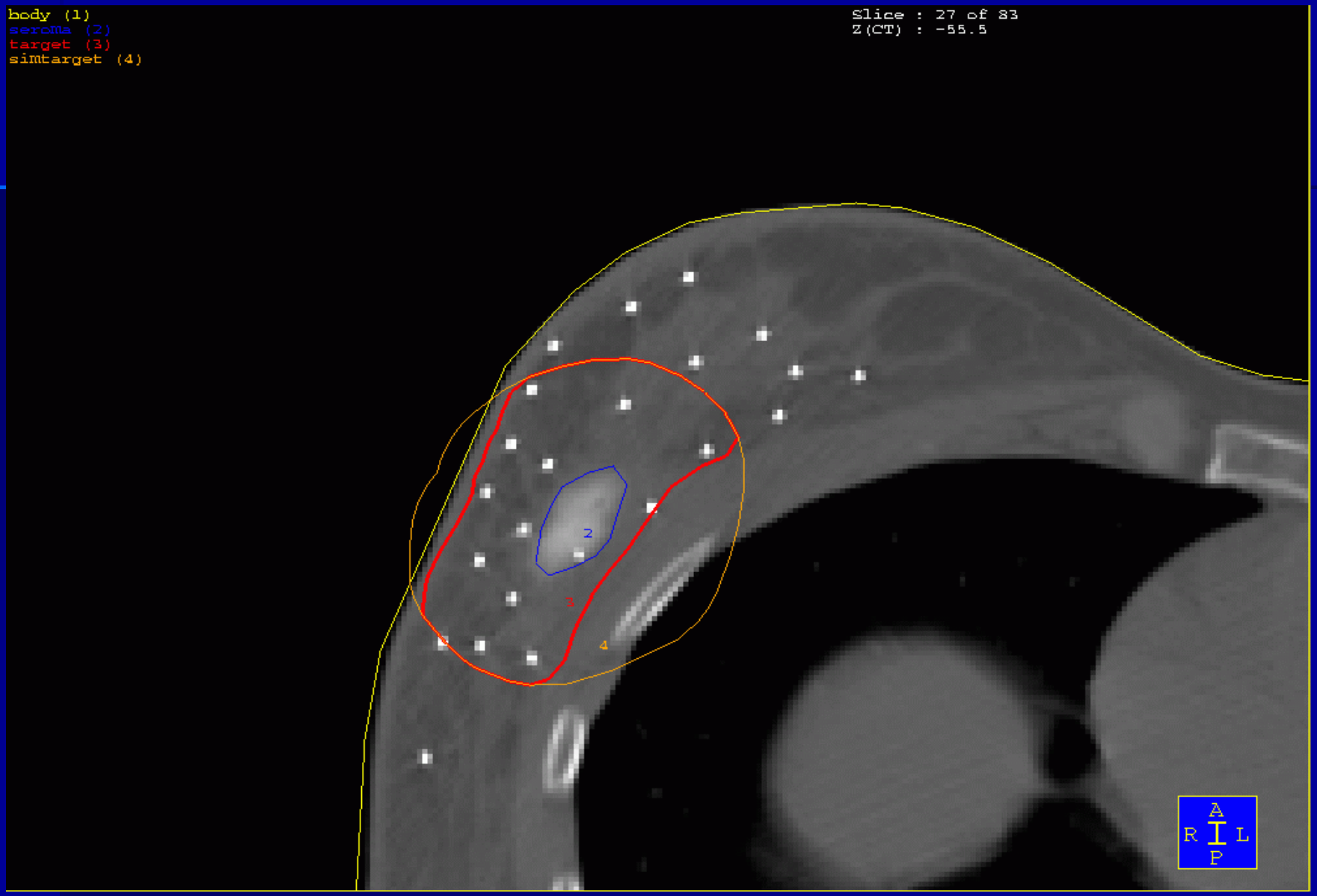
Breast Brachytherapy
Target Volume

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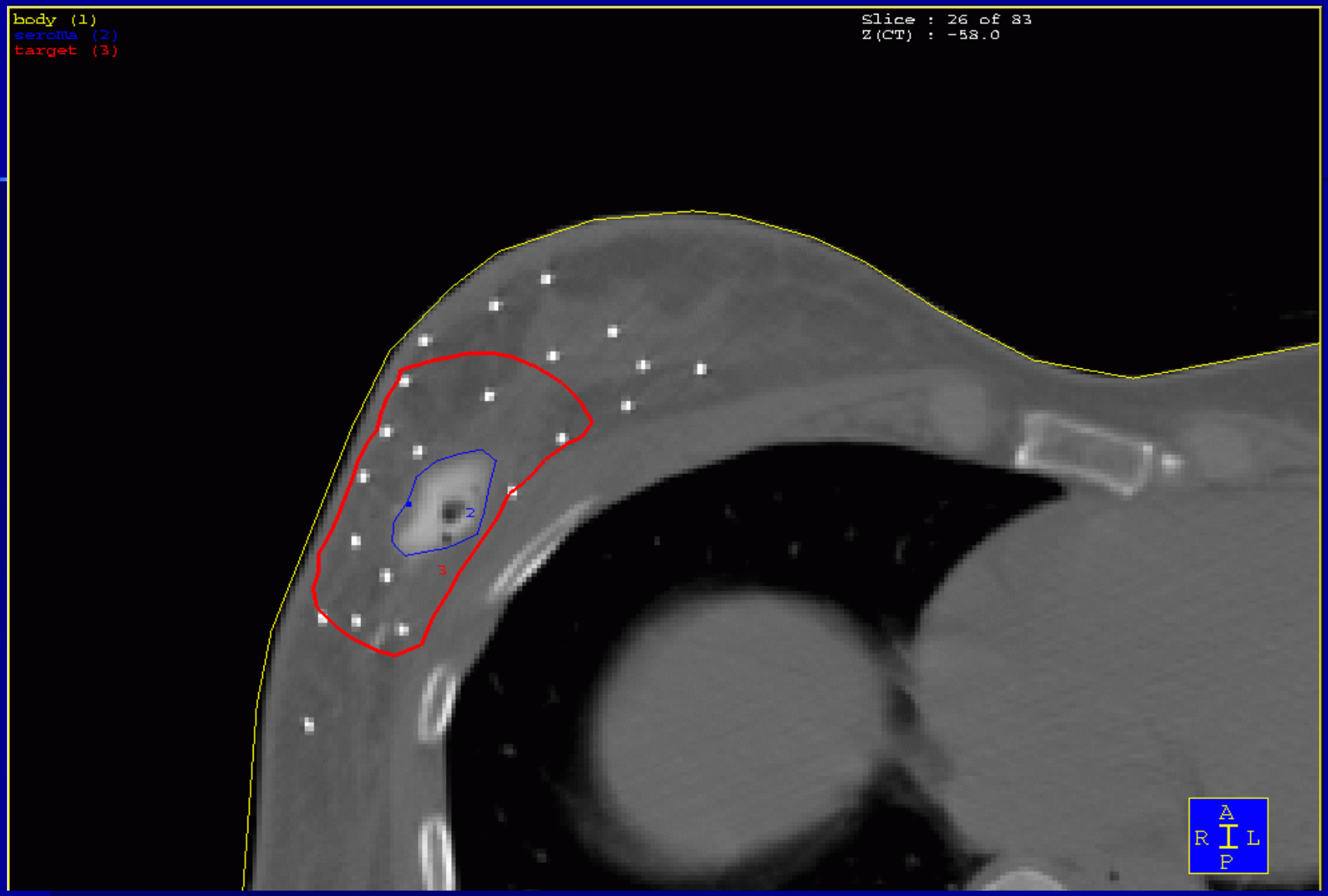
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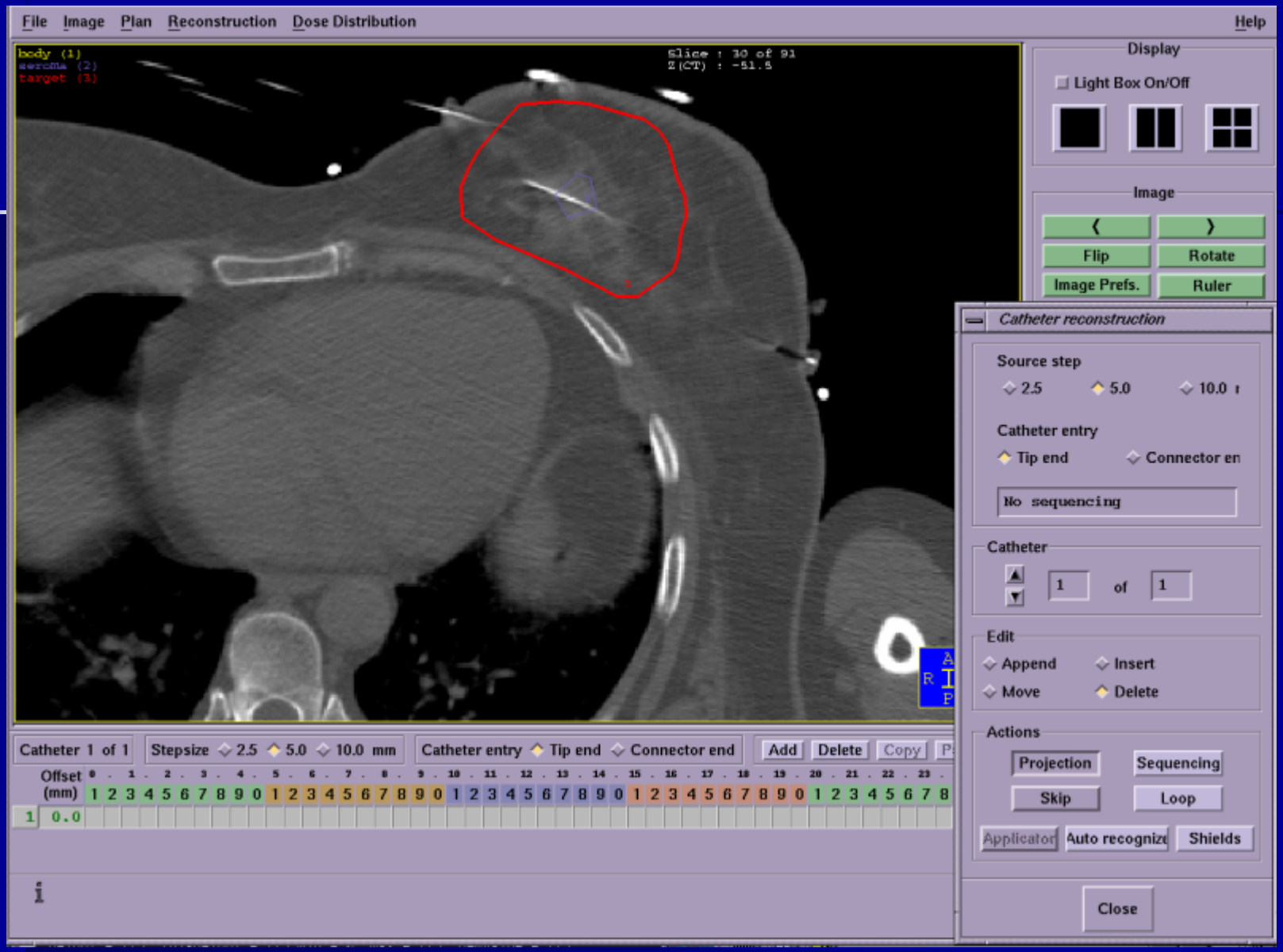
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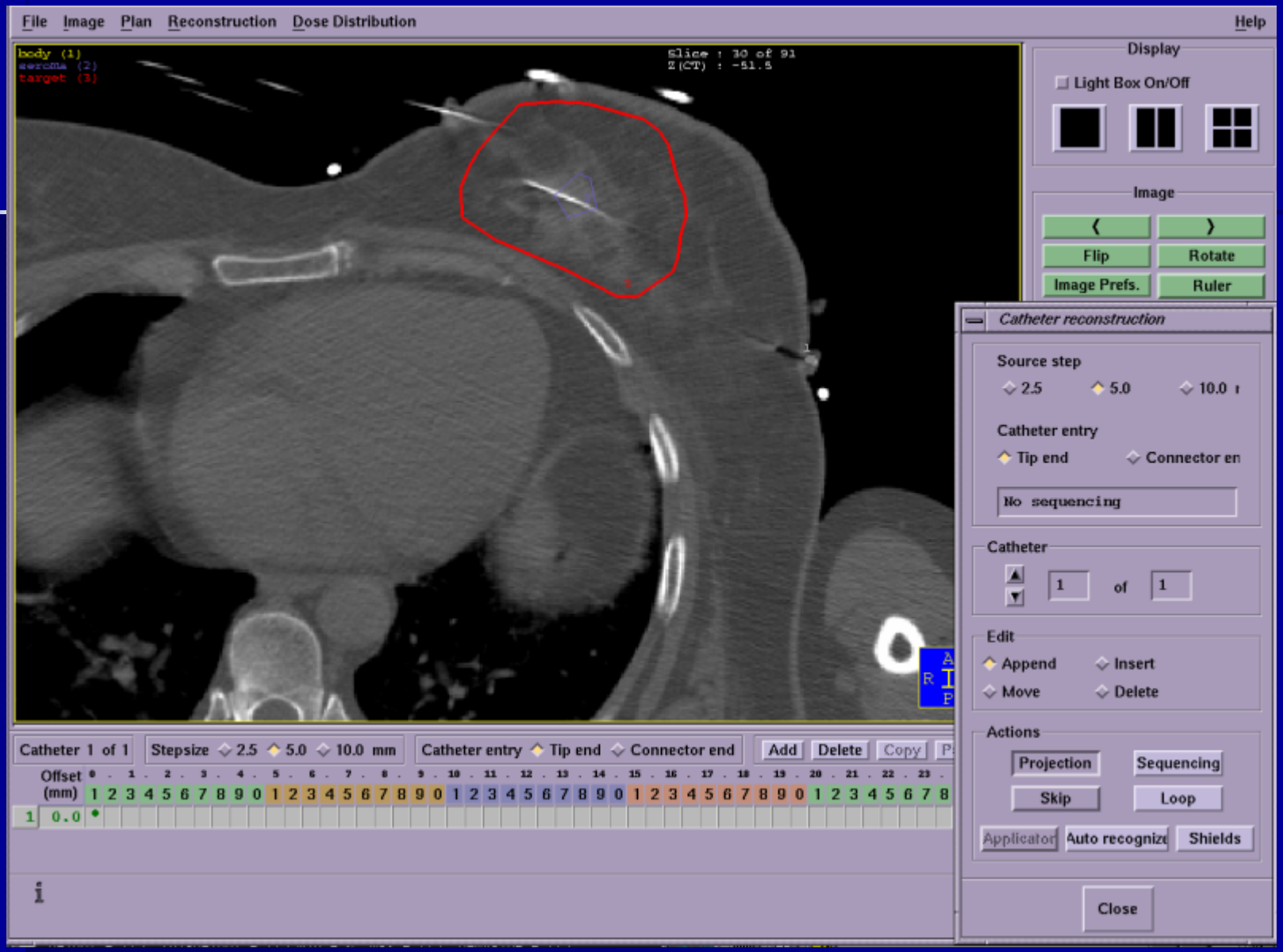
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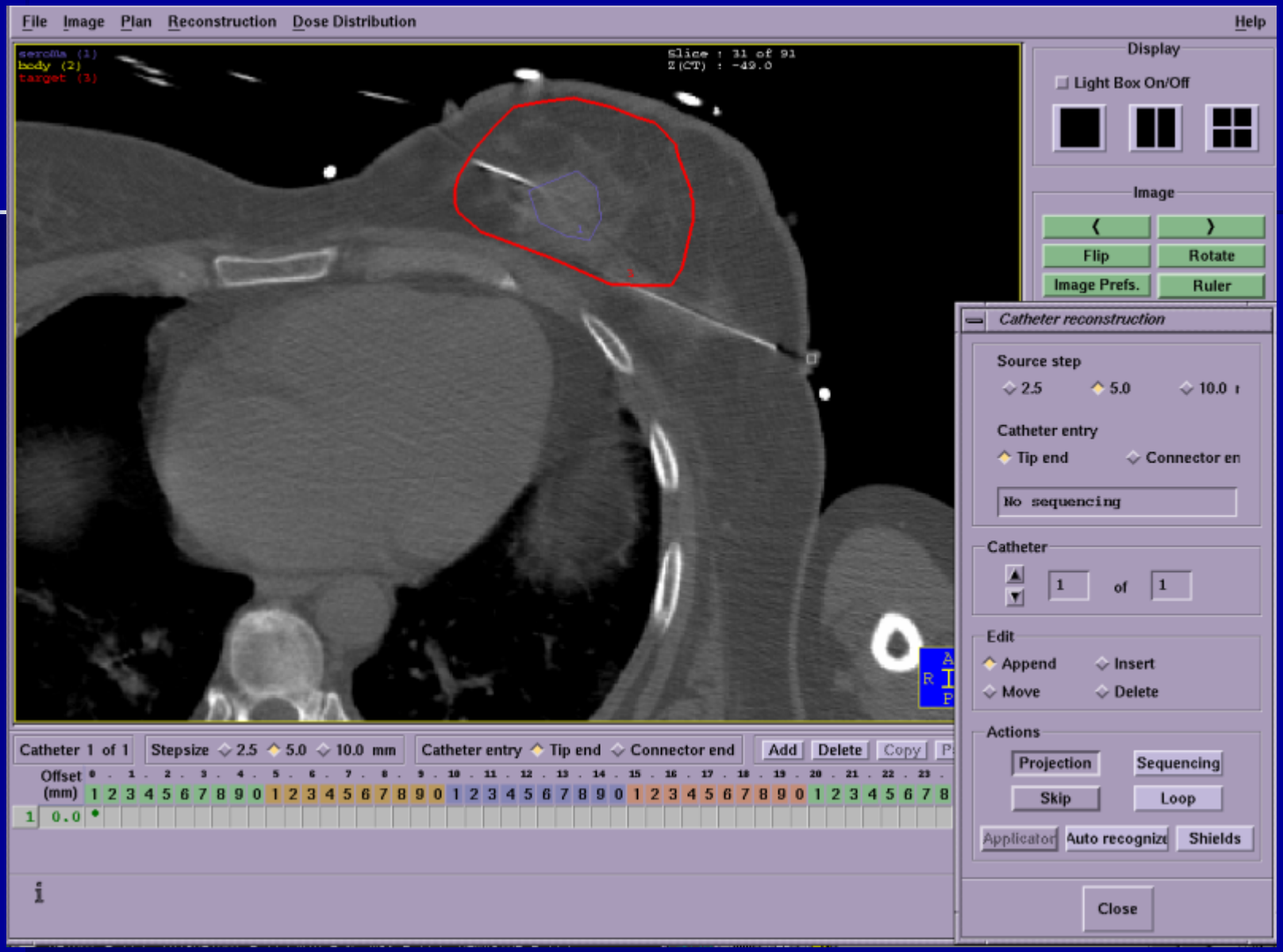
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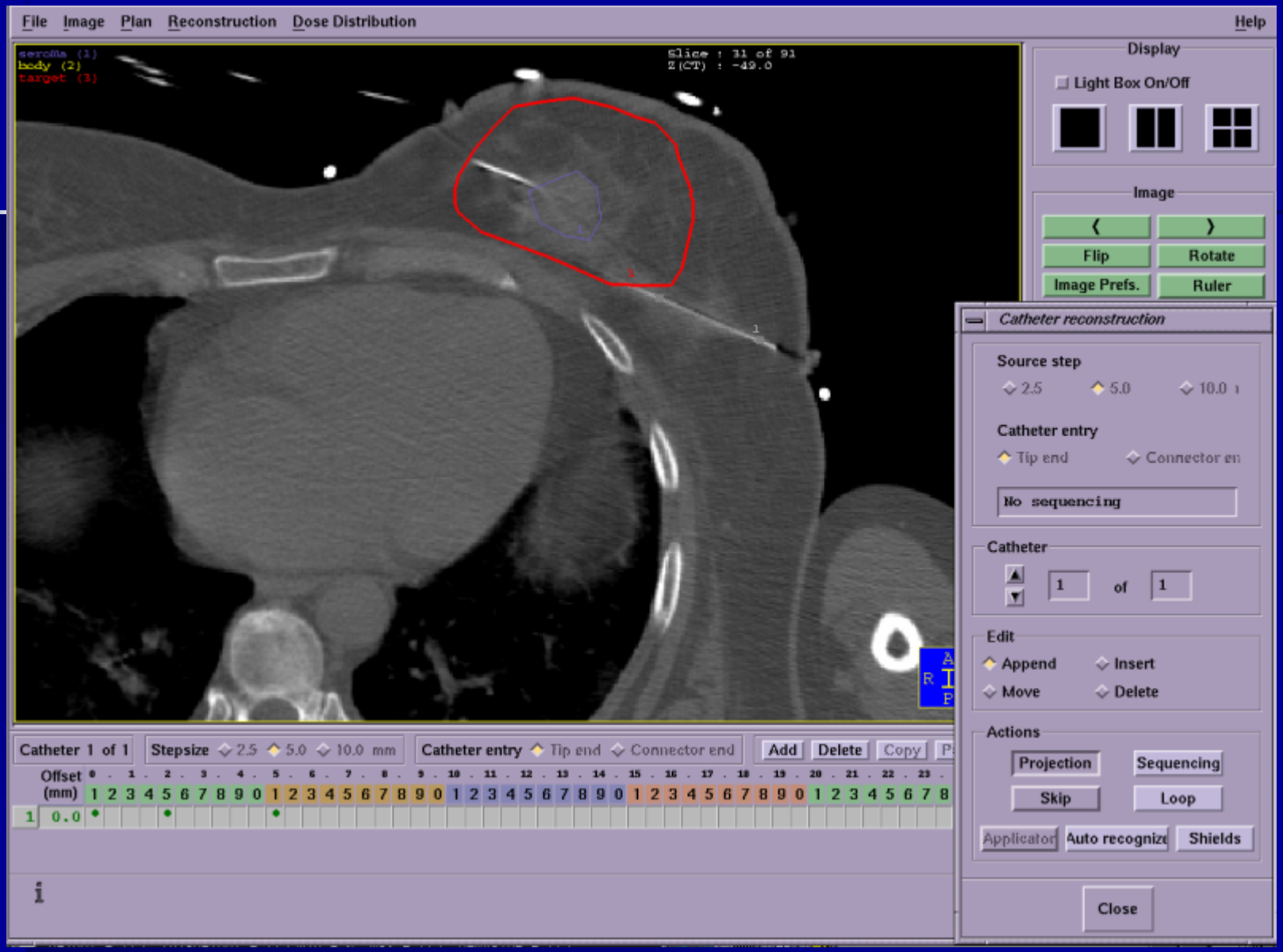
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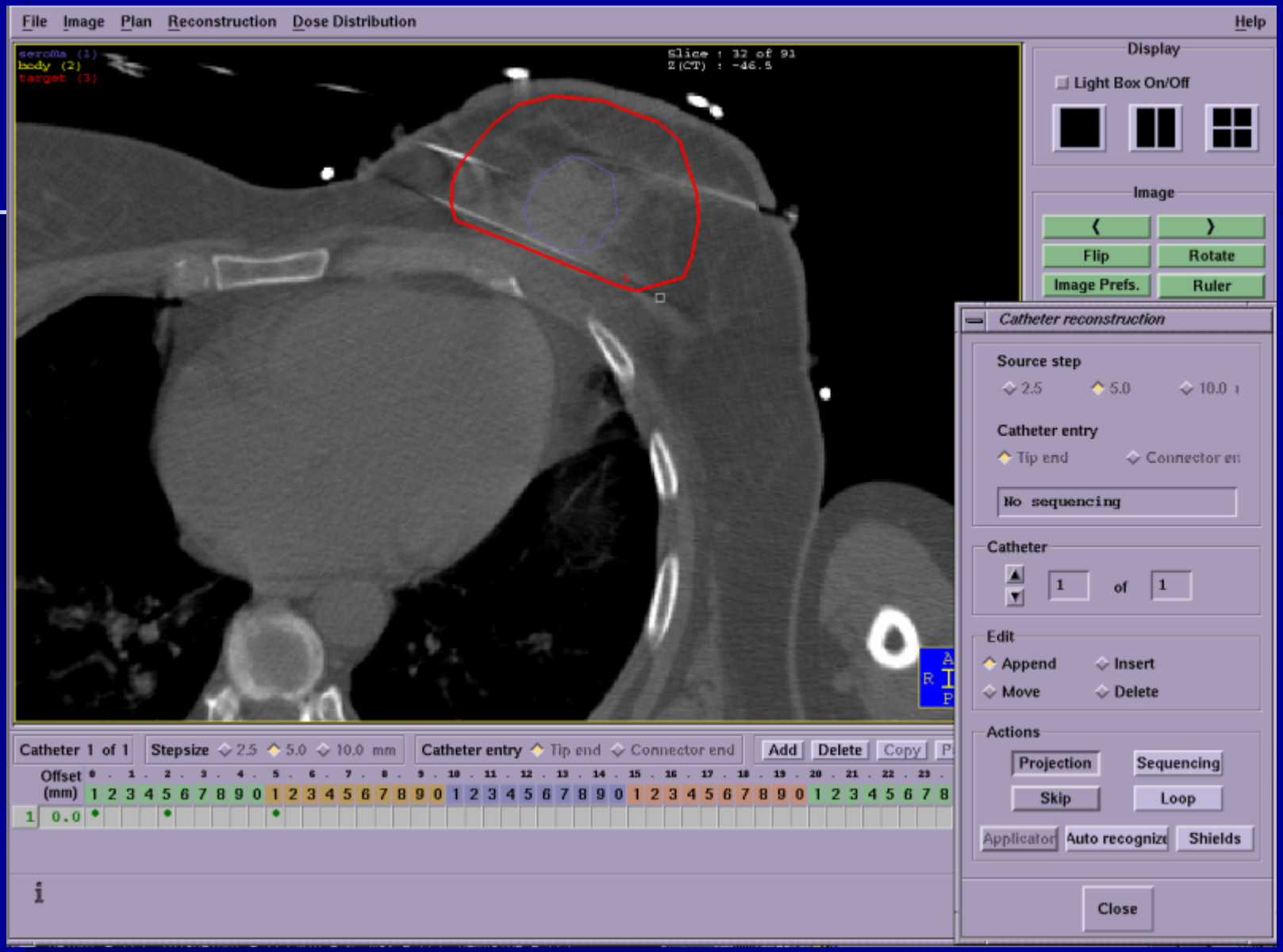
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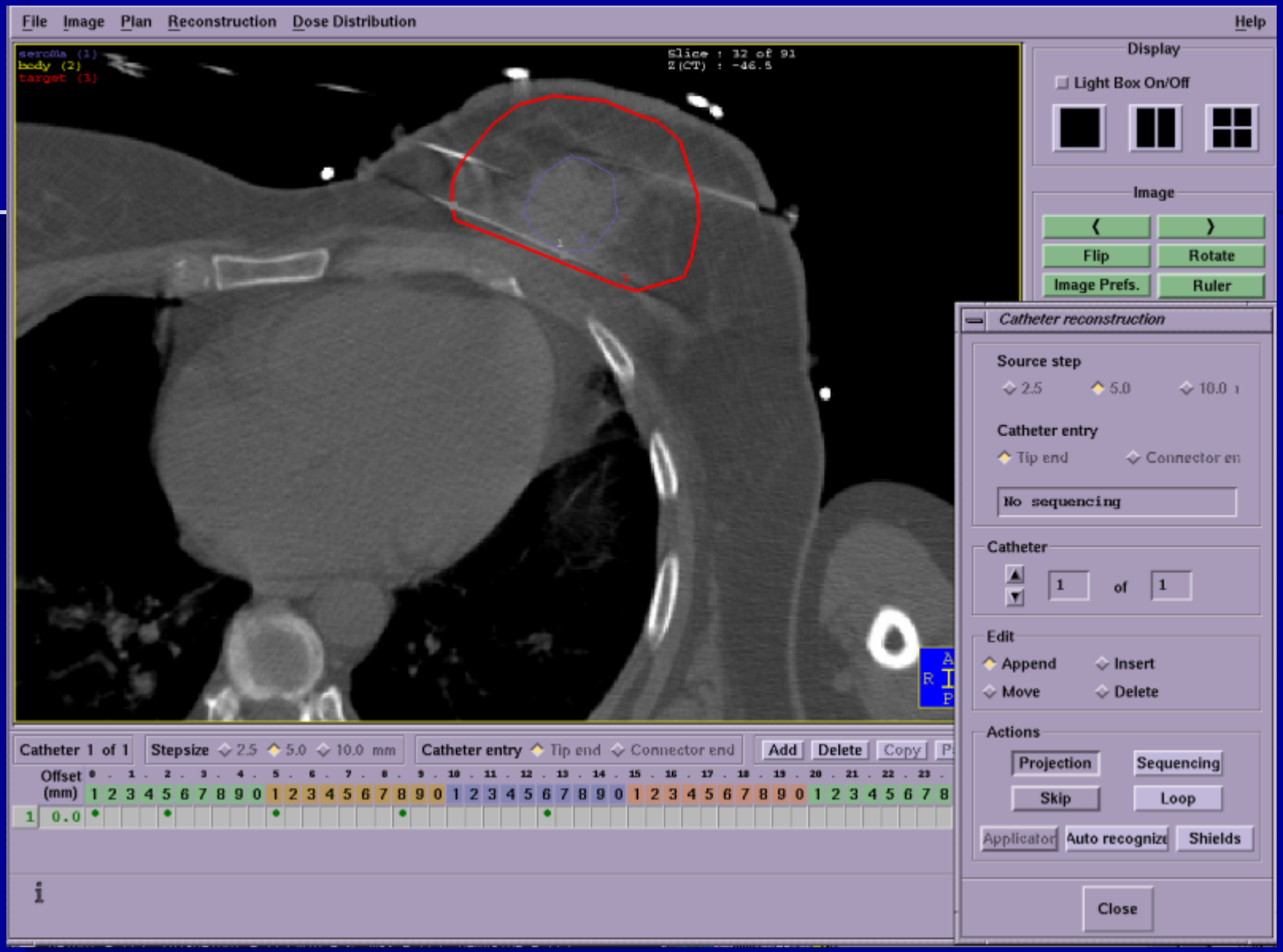
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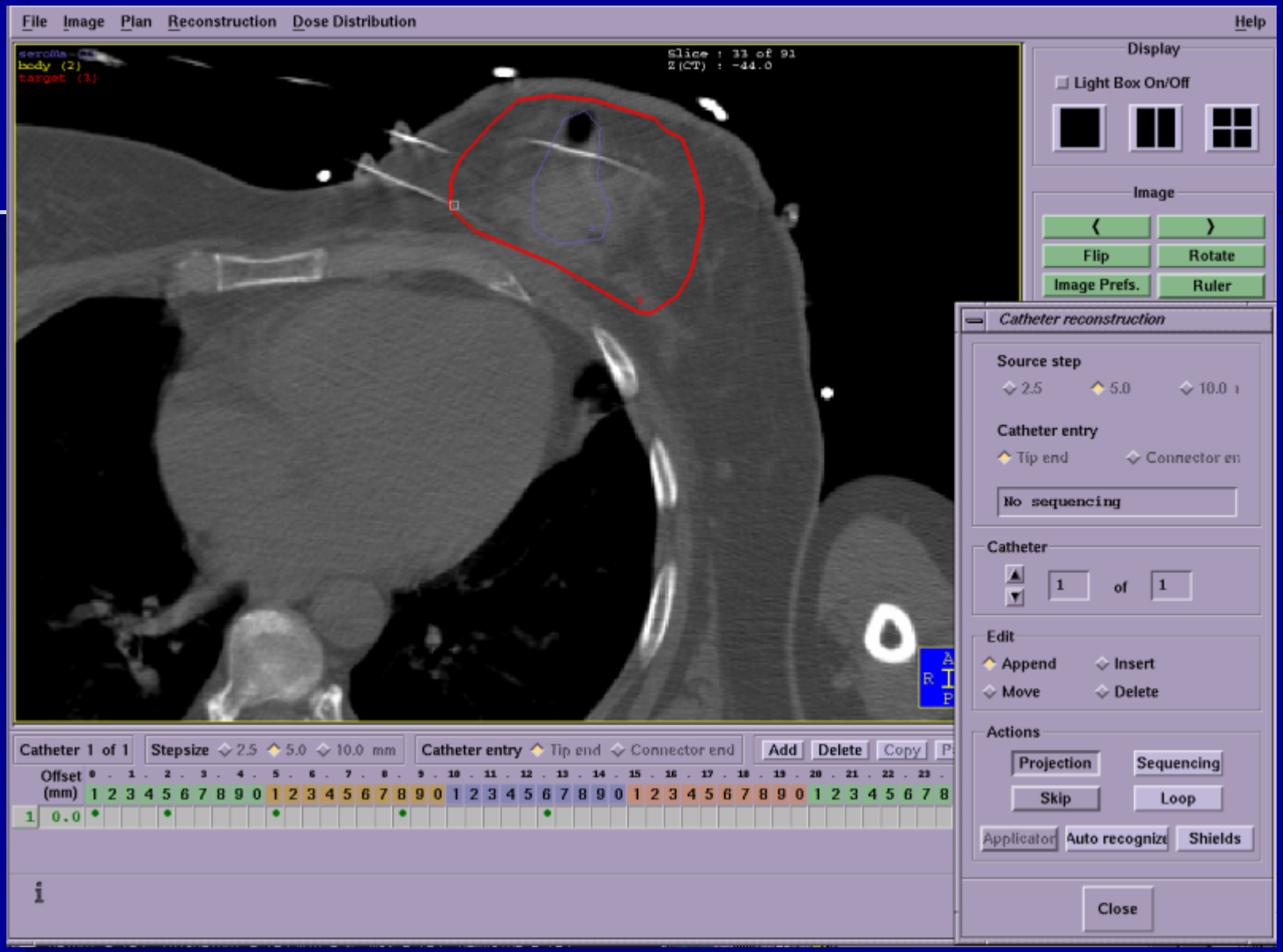
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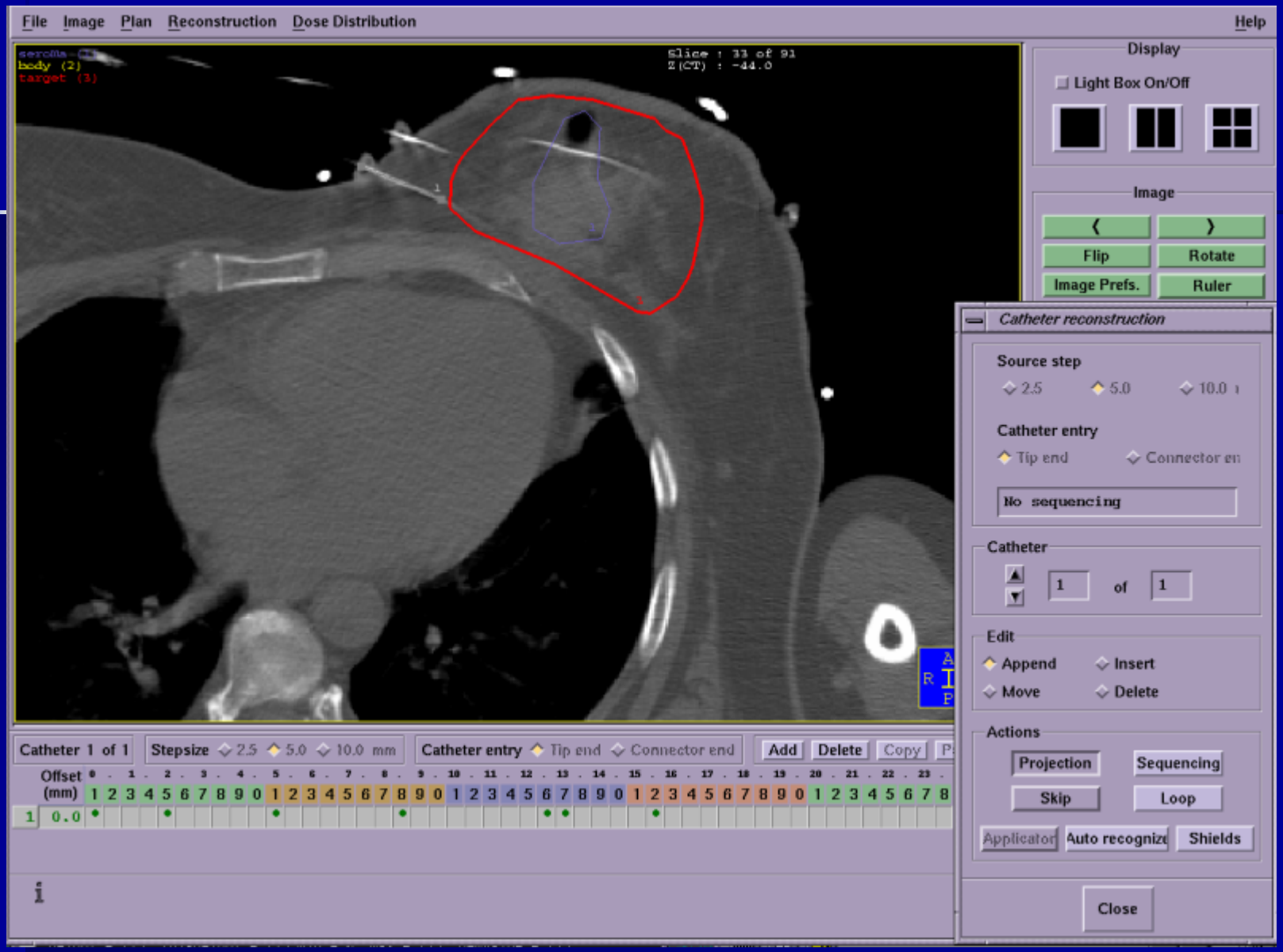
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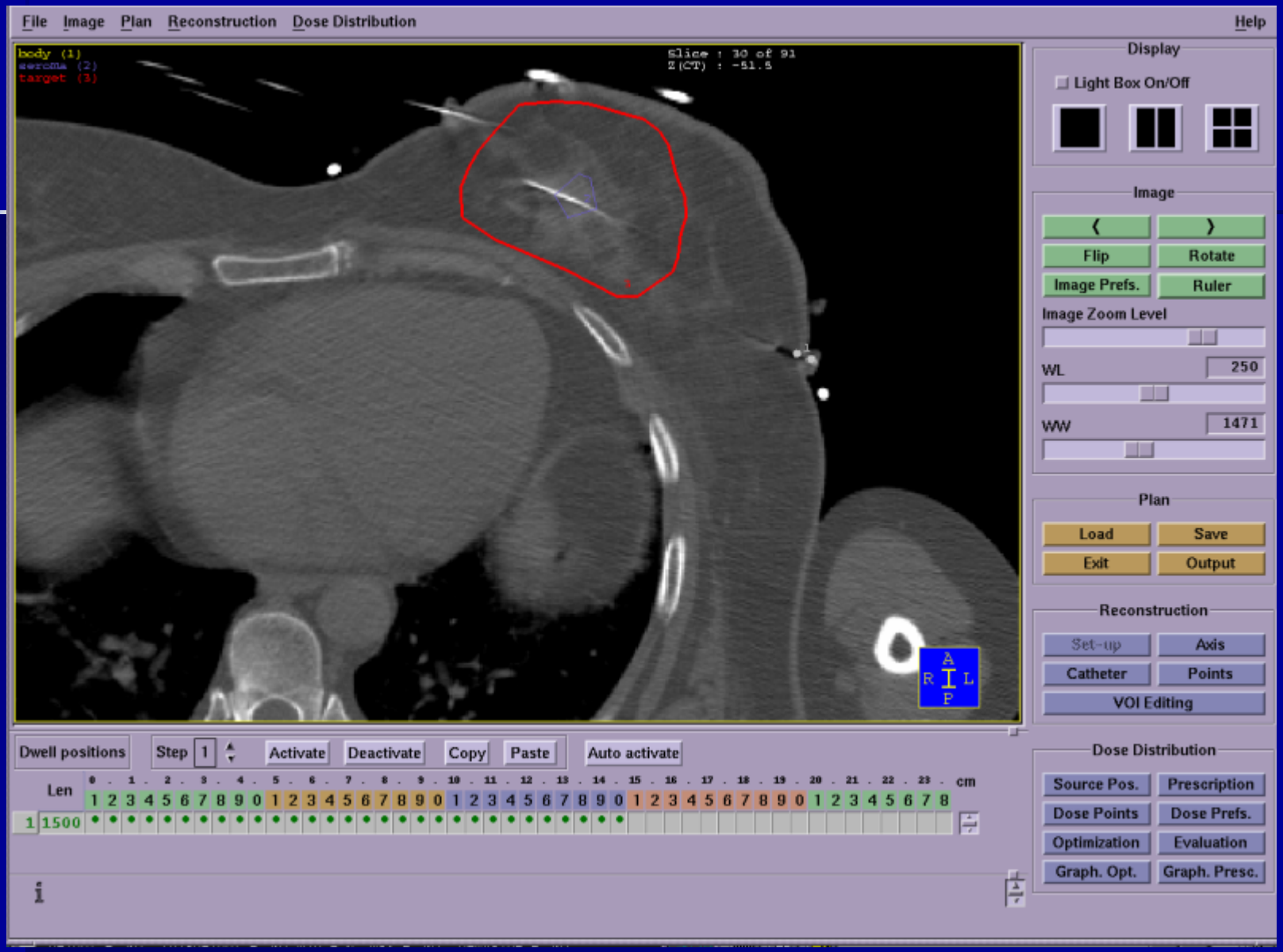
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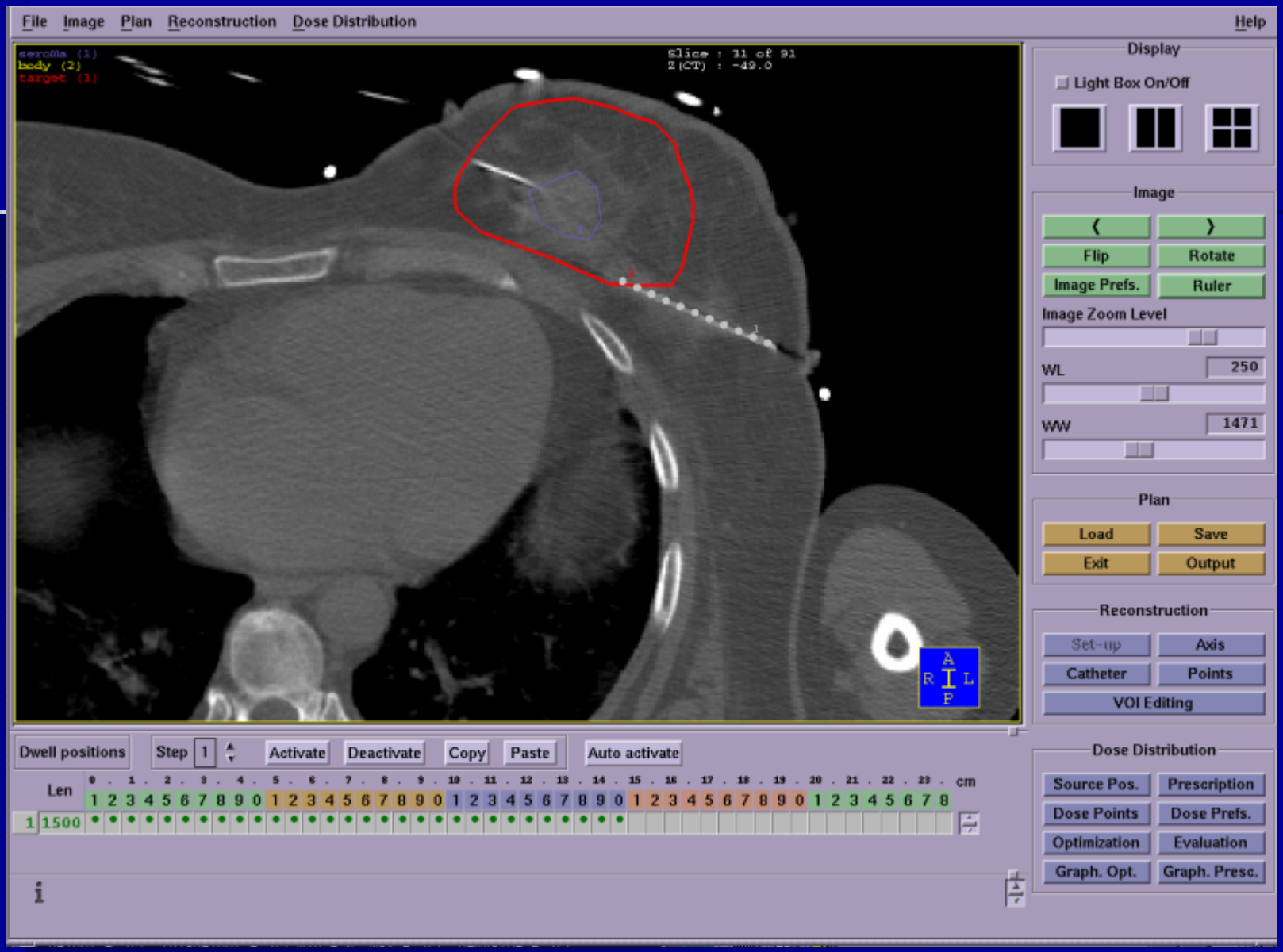
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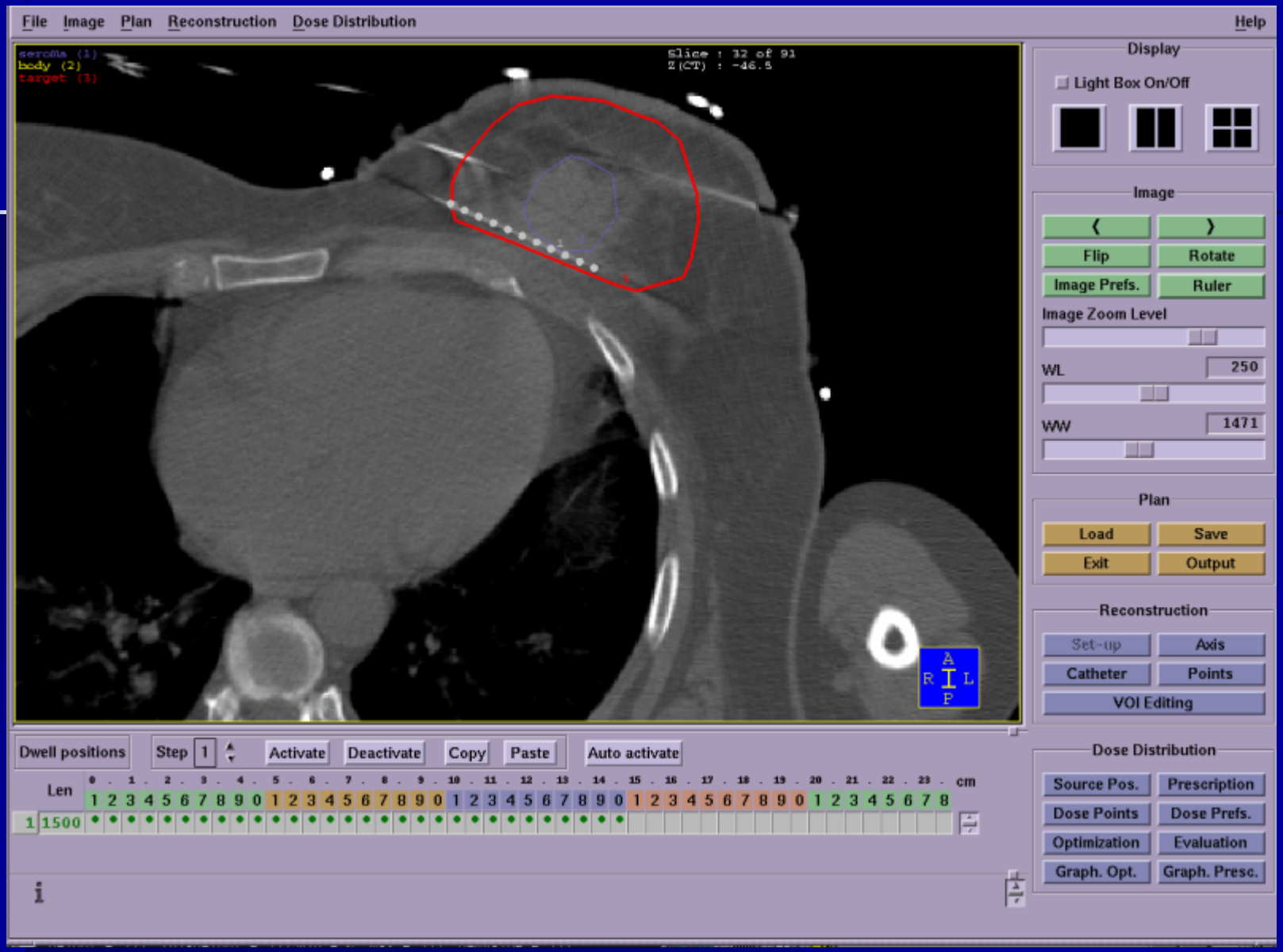
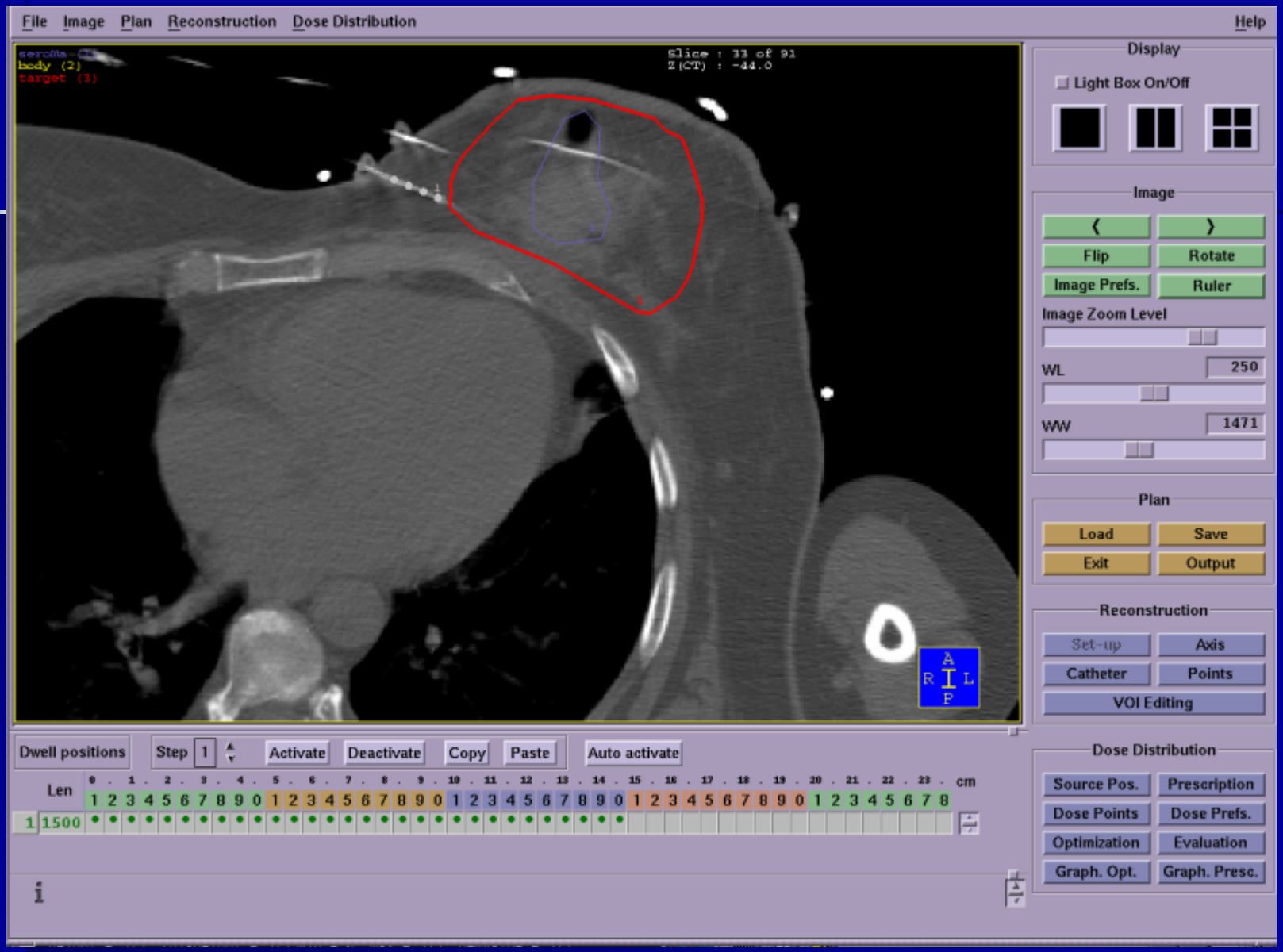
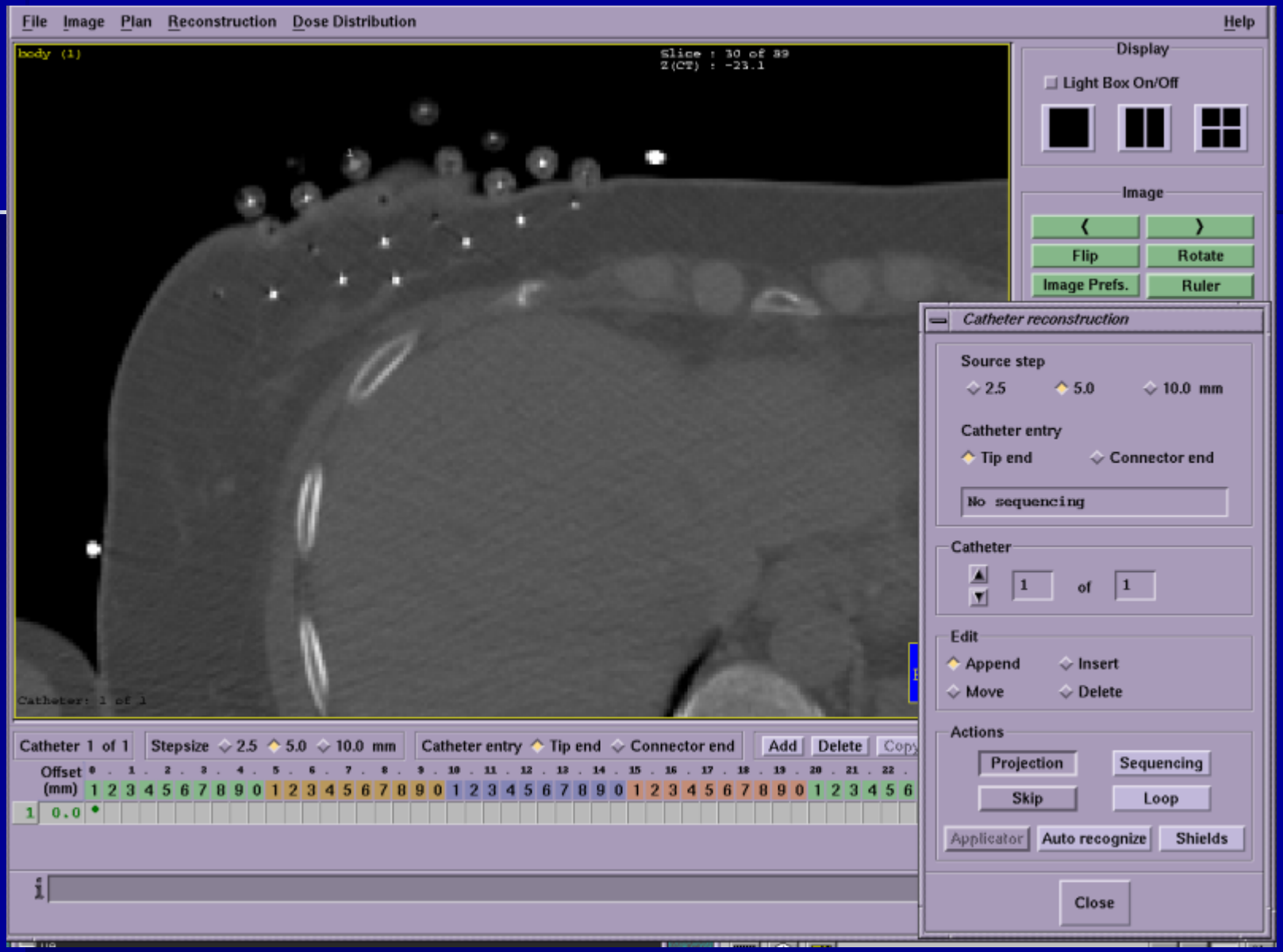
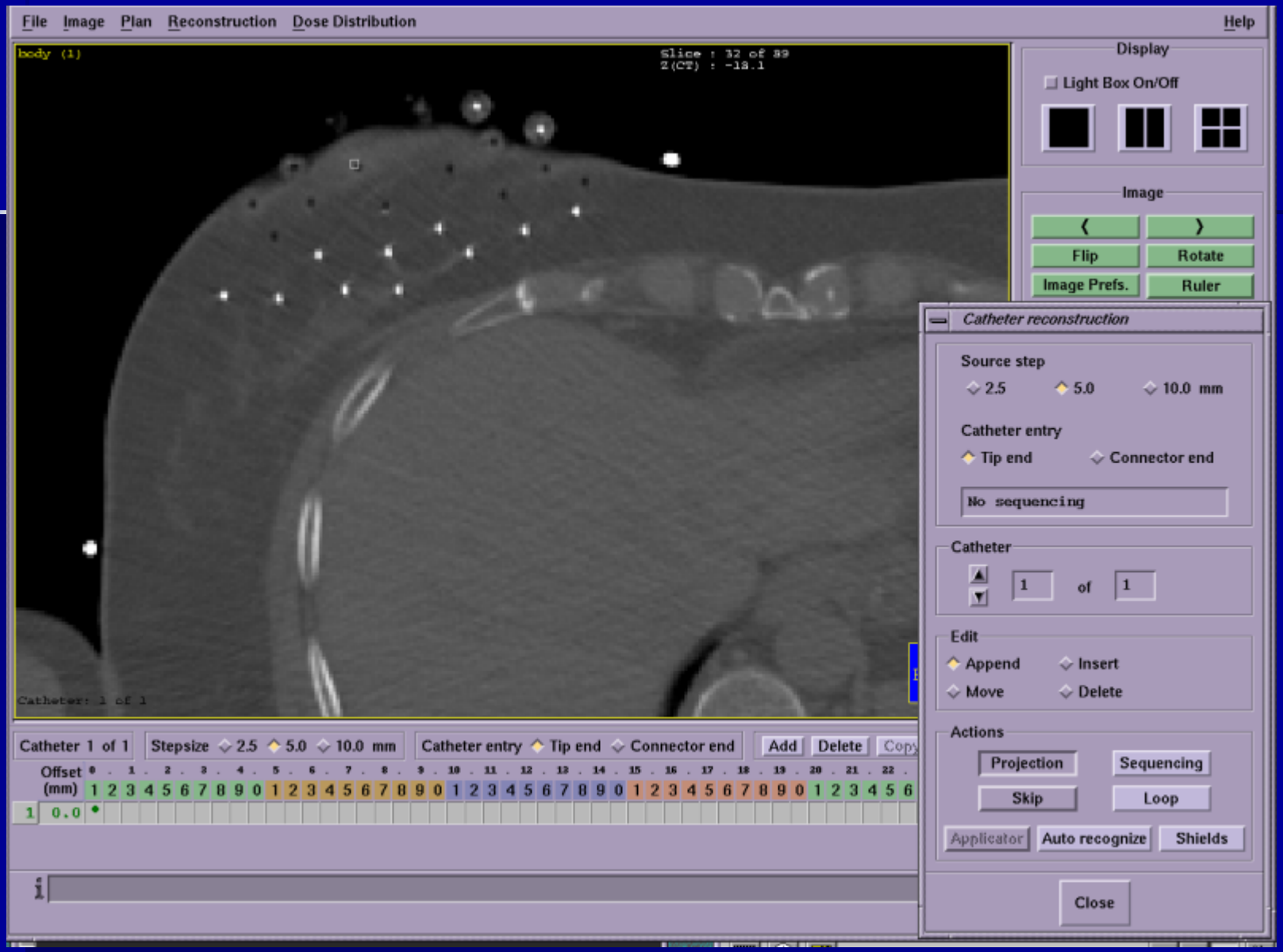
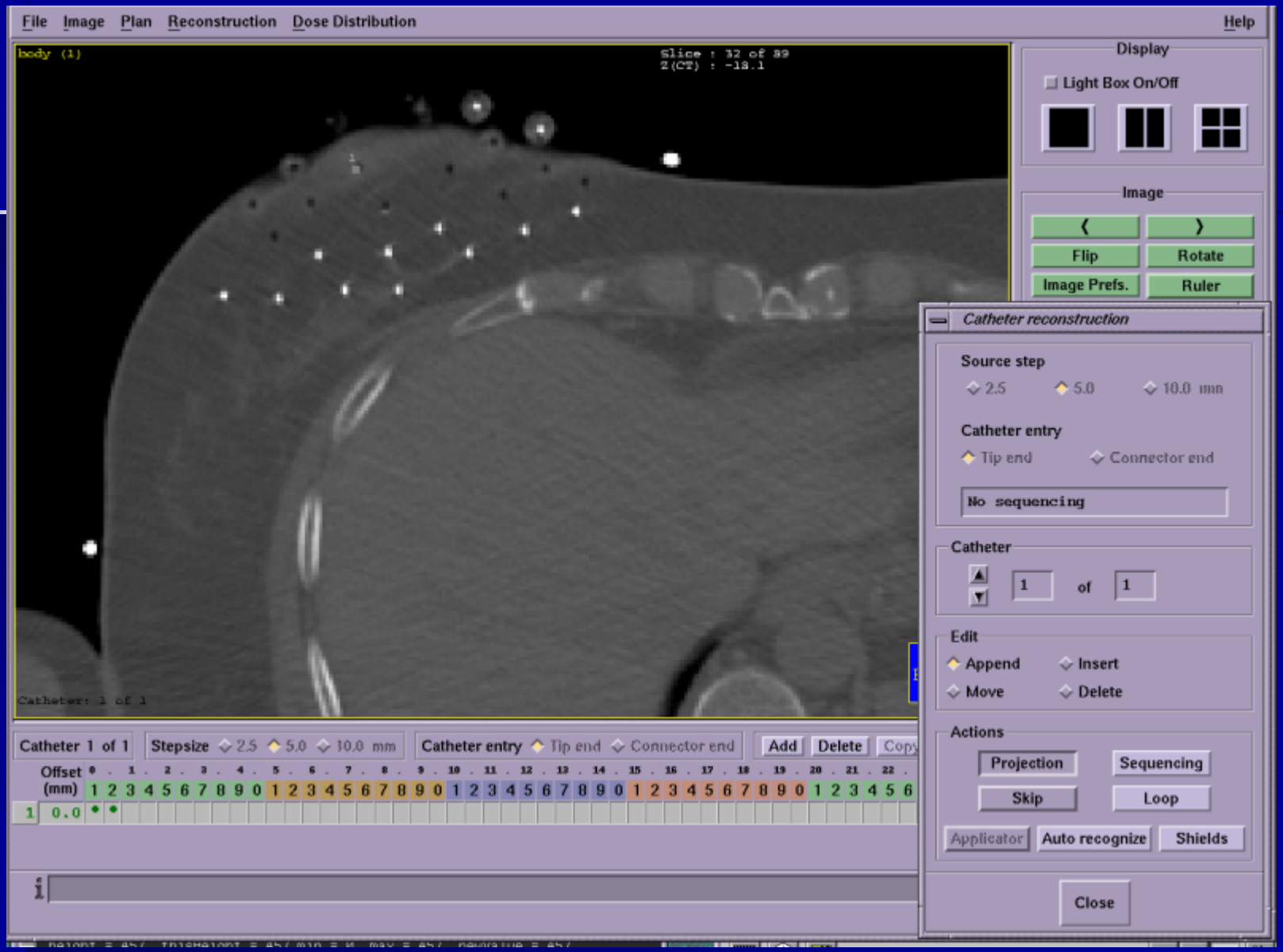
Graph. Opt.
Graph. Presc.
Dwell positions
Step
Activate
Deactivate
Copy
Paste
Auto activate
Len
cm
1500

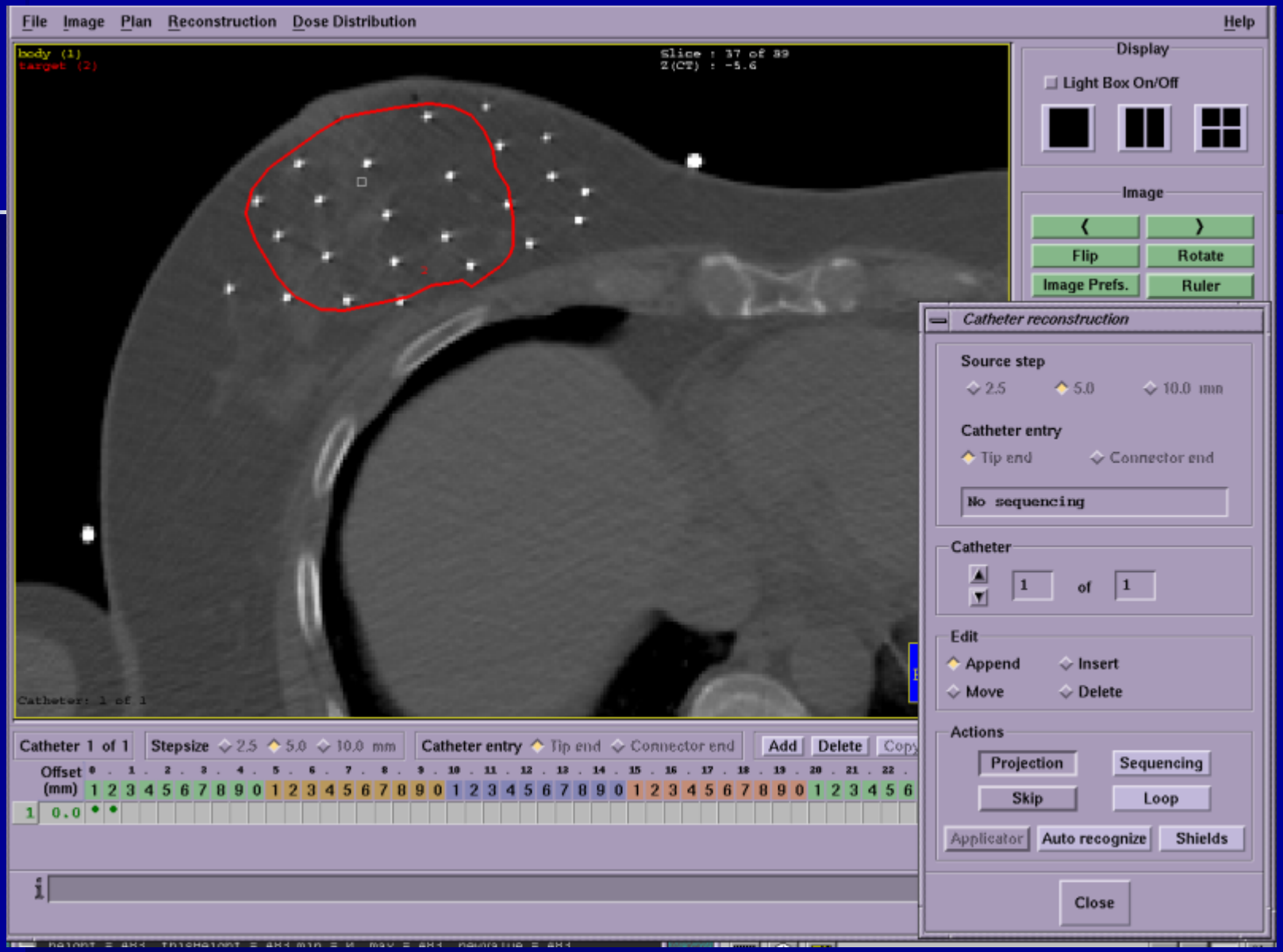

File
Image
Plan
Reconstruction
Dose Distribution
Help
sarcoma (1)
body (2)
target (3)
Slice : 32 of 91
Z(CT) : -46.5
A
R
L
P
Display
Light Box On/Off
Image
Flip
Rotate
Image Prefs.
Ruler
Image Zoom Level
WL
250
WW
1471
Plan
Load
Save
Exit
Output
Reconstruction
Set-up
Axis
Catheter
Points
VOI Editing
Dwell positions
Step
1
Activate
Deactivate
Copy
Paste
Auto activate
Dose Distribution
Source Pos.
Prescription
Dose Points
Dose Prefs.
Optimization
Evaluation
Graph. Opt.
Graph. Presc.
Len
cm
1
1500

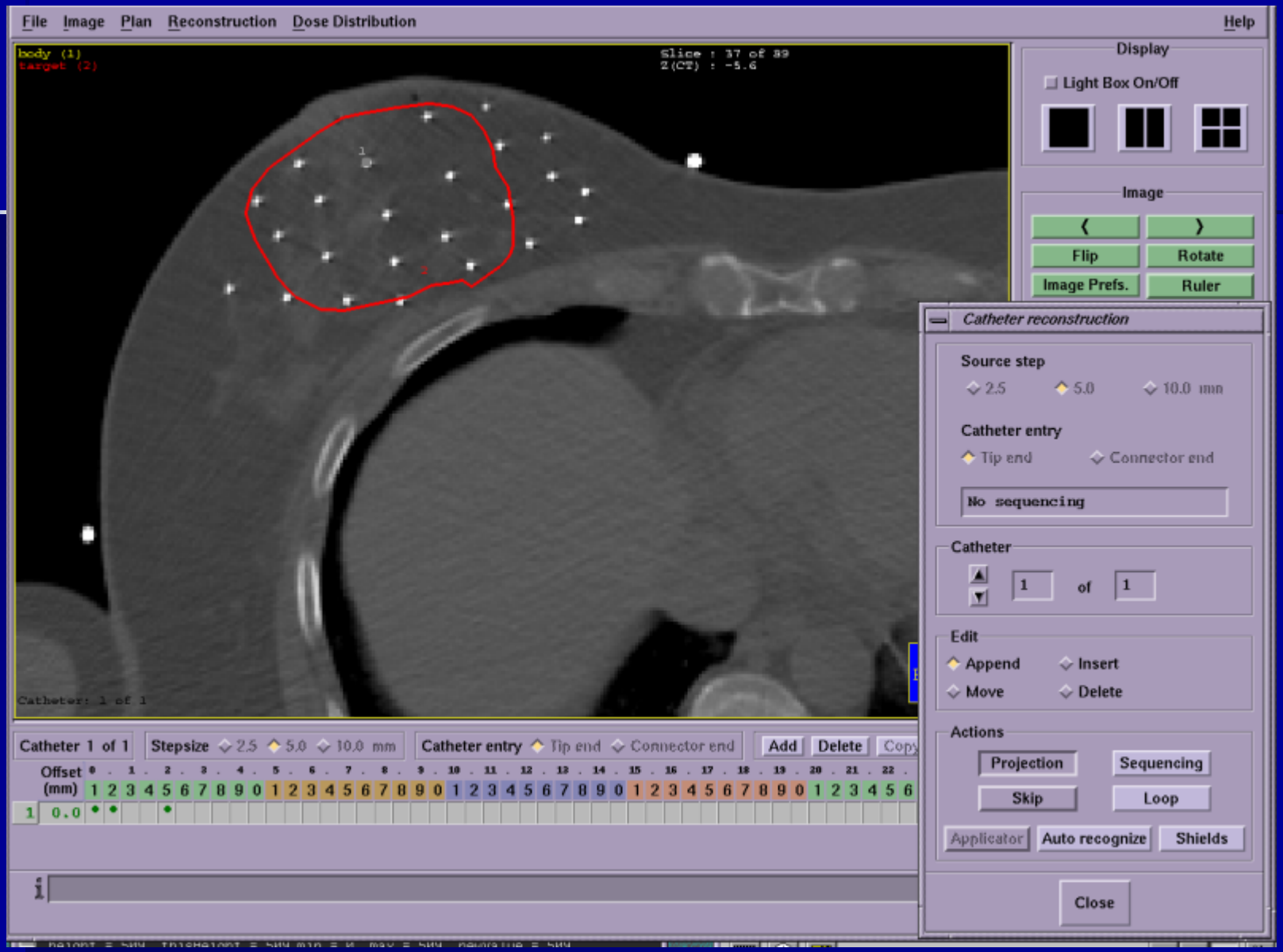

File
Image
Plan
Reconstruction
Dose Distribution
Help
sarcoma
body (2)
target (3)
Slice : 33 of 91
Z(CT) : -44.0
A
R
L
P
Display
Light Box On/Off
Image
Flip
Rotate
Image Prefs.
Ruler
Image Zoom Level
WL
250
WW
1471
Plan
Load
Save
Exit
Output
Reconstruction
Set-up
Axis
Catheter
Points
VOI Editing
Dose Distribution
Source Pos.
Prescription
Dose Points
Dose Prefs.
Optimization
Evaluation
Graph. Opt.
Graph. Presc.
Dwell positions
Step
1
Activate
Deactivate
Copy
Paste
Auto activate
Len
cm
1
1500

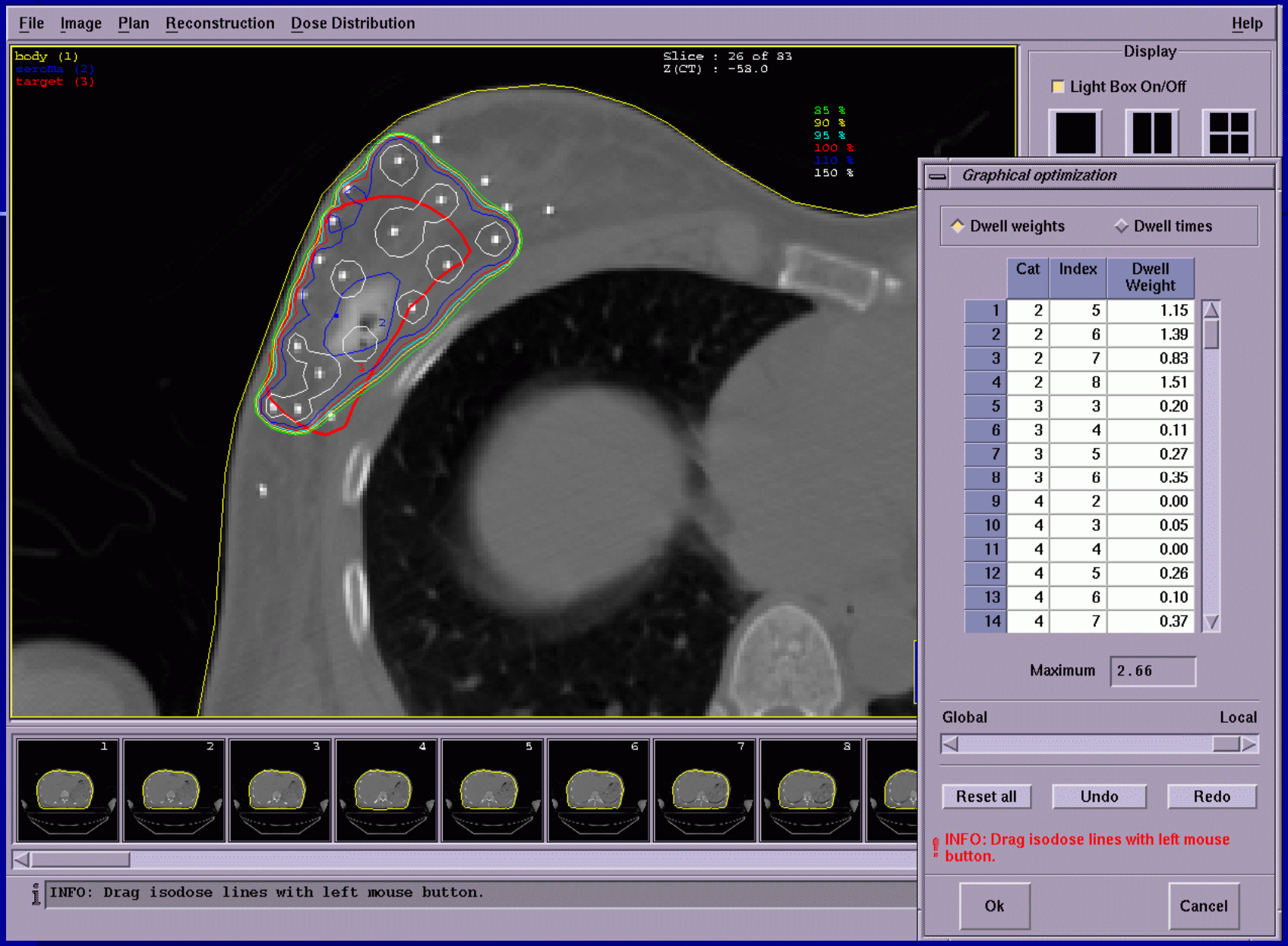

File
Image
Plan
Reconstruction
Dose Distribution
Help
body (1)
Slice : 30 of 39
Z(CT) : -23.1
Catheter: 1 of 1
Display
Light Box On/Off
Image
Flip
Rotate
Image Prefs.
Ruler
Catheter reconstruction
Source step
2.5
5.0
10.0 mm
Catheter entry
Tip end
Connector end
No sequencing
Catheter
1
of
1
Edit
Append
Insert
Move
Delete
Actions
Projection
Sequencing
Skip
Loop
Applicator
Auto recognize
Shields
Close
Catheter 1 of 1
Stepsize
2.5
5.0
10.0 mm
Catheter entry
Tip end
Connector end
Add
Delete
Copy
Offset (mm)
0.0

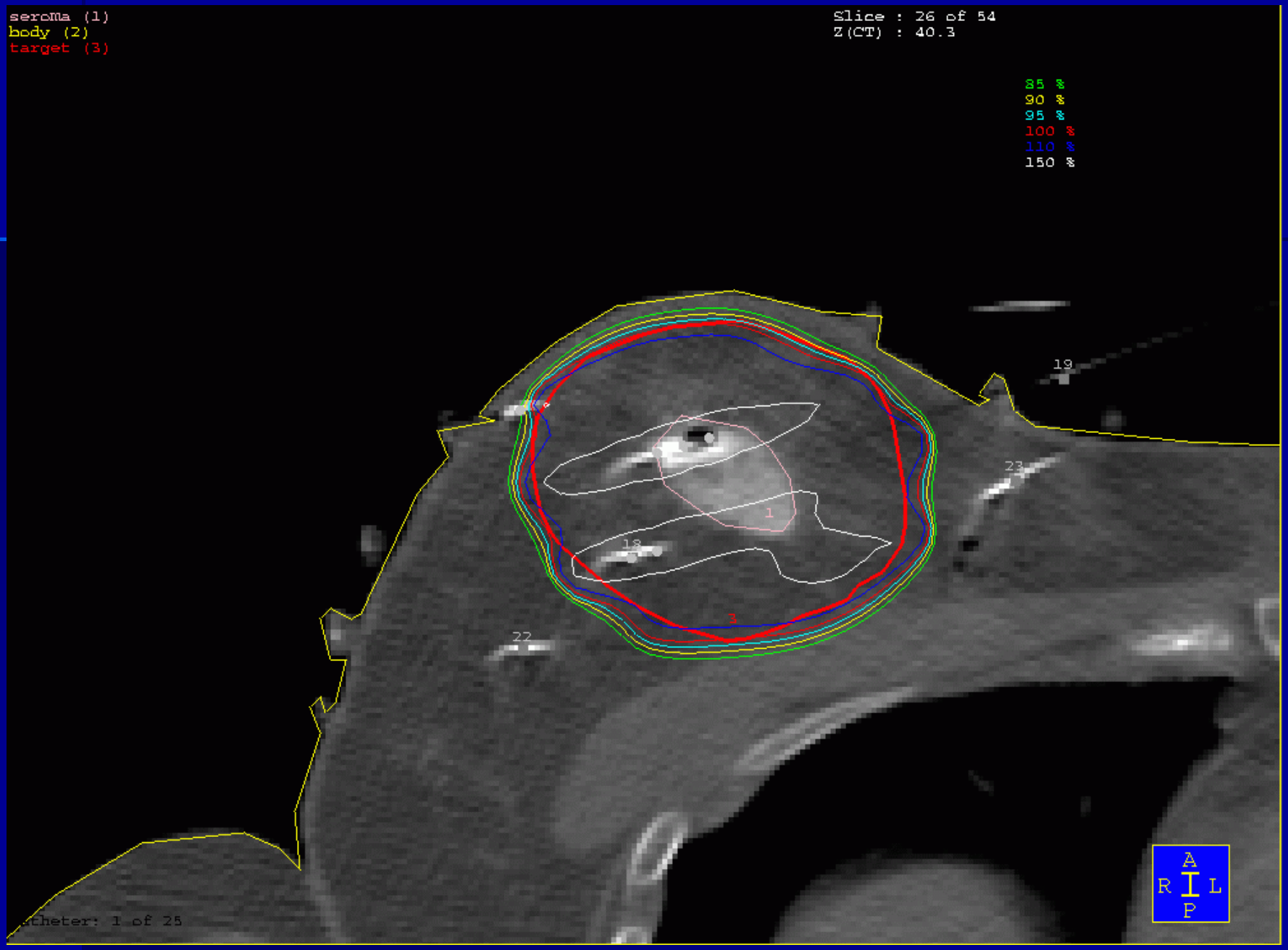

File
Image
Plan
Reconstruction
Dose Distribution
Help
body (1)
Slice : 32 of 39
Z(CT) : -18.1
Catheter: 1 of 1
Display
Light Box On/Off
Image
Flip
Rotate
Image Prefs.
Ruler
Catheter reconstruction
Source step
2.5
5.0
10.0 mm
Catheter entry
Tip end
Connector end
No sequencing
Catheter
1
of
1
Edit
Append
Insert
Move
Delete
Actions
Projection
Sequencing
Skip
Loop
Applicator
Auto recognize
Shields
Close
Catheter 1 of 1
Stepsize
2.5
5.0
10.0 mm
Catheter entry
Tip end
Connector end
Add
Delete
Copy
Offset (mm)
0.0

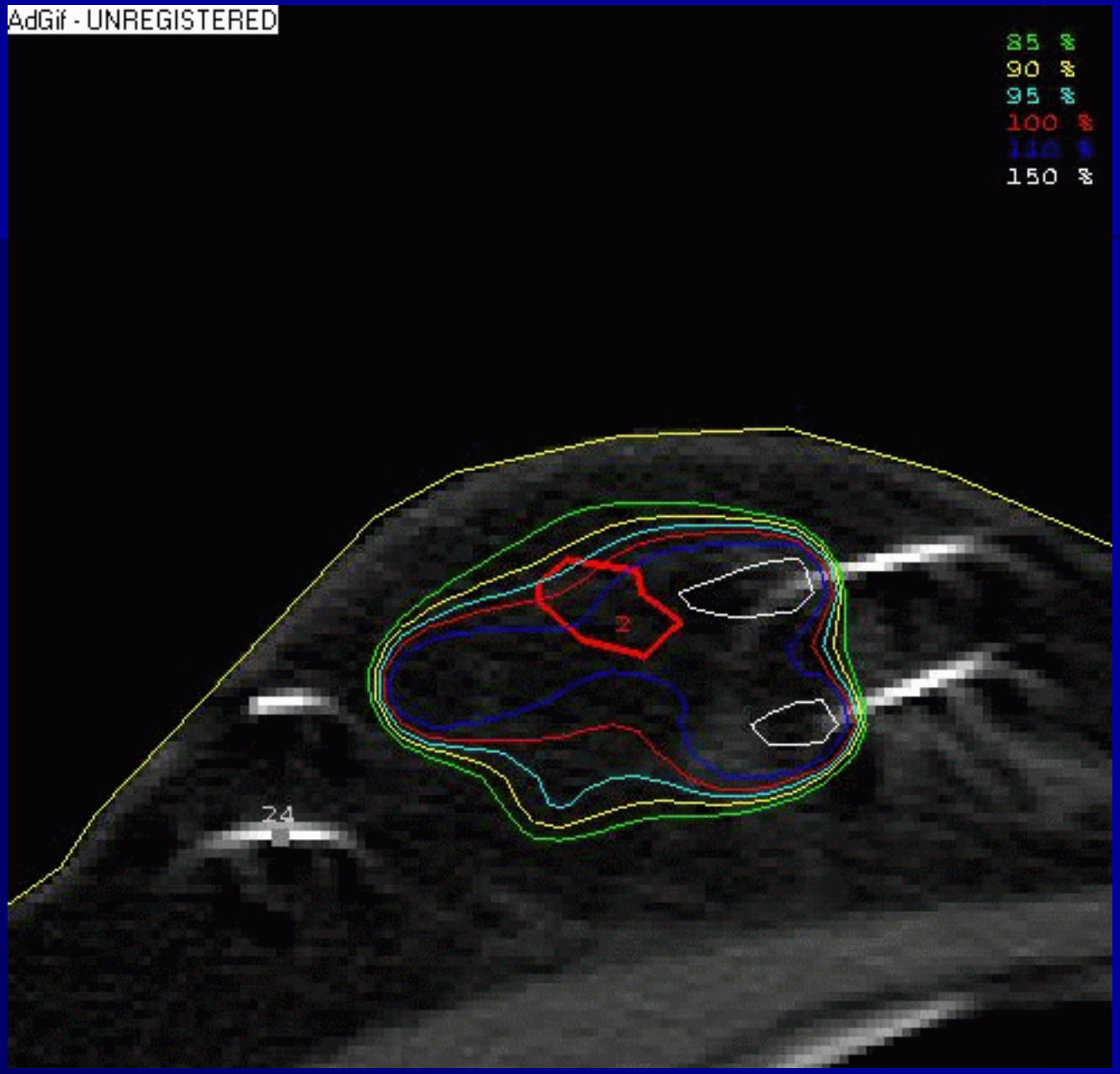

File
Image
Plan
Reconstruction
Dose Distribution
Help
body (1)
Slice : 32 of 39
Z(CT) : -18.1
Catheter: 1 of 1
Display
Light Box On/Off
Image
Flip
Rotate
Image Prefs.
Ruler
Catheter reconstruction
Source step
2.5
5.0
10.0 mm
Catheter entry
Tip end
Connector end
No sequencing
Catheter
1
of
1
Edit
Append
Insert
Move
Delete
Actions
Projection
Sequencing
Skip
Loop
Applicator
Auto recognize
Shields
Close
Catheter 1 of 1
Stepsize
2.5
5.0
10.0 mm
Catheter entry
Tip end
Connector end
Add
Delete
Copy
Offset (mm)
0.0

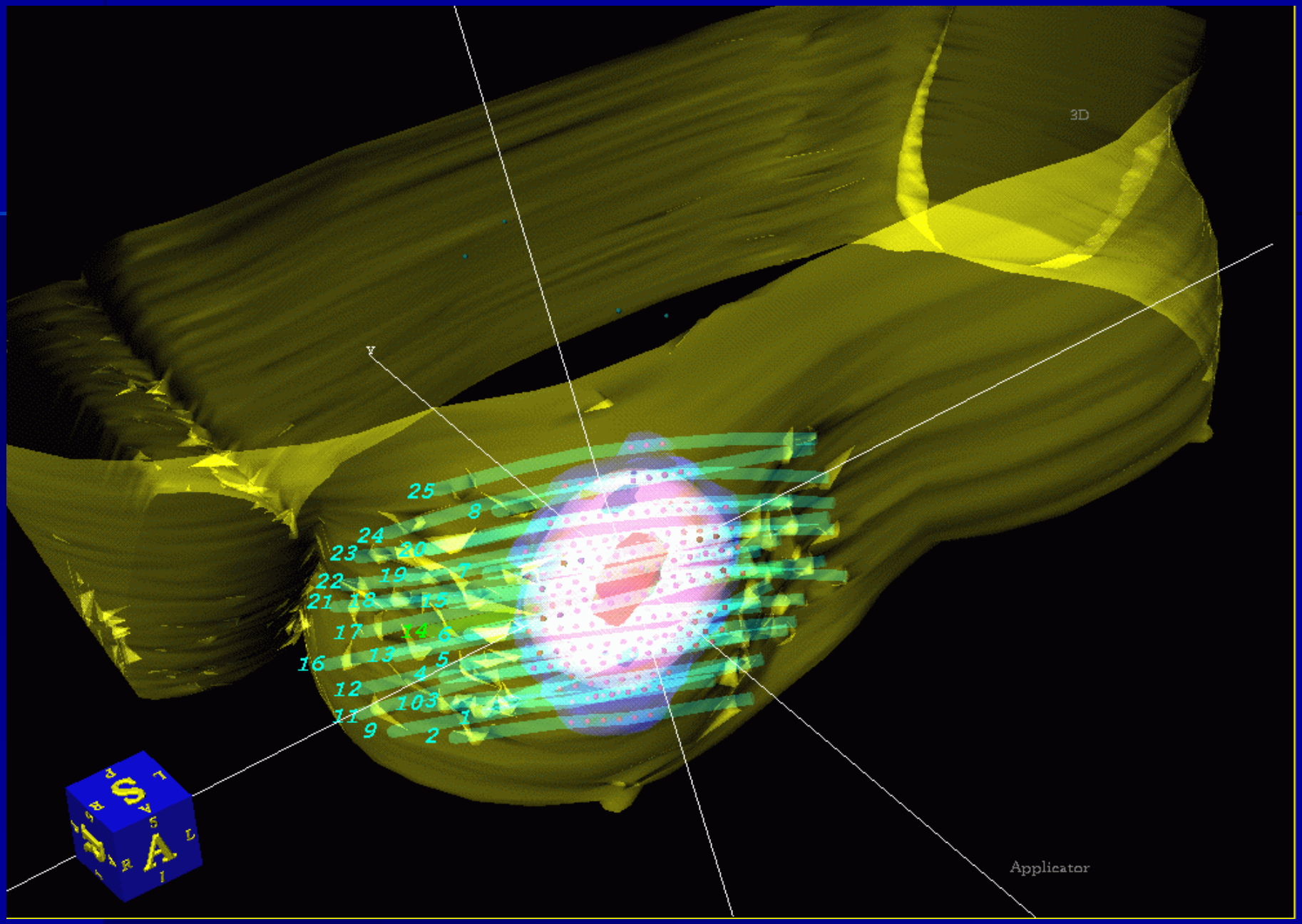

File
Image
Plan
Reconstruction
Dose Distribution
Help
body (1)
target (2)
Slice : 37 of 39
Z(CT) : -5.6
Catheter: 1 of 1
Display
Light Box On/Off
Image
Flip
Rotate
Image Prefs.
Ruler
Catheter reconstruction
Source step
2.5
5.0
10.0 mm
Catheter entry
Tip end
Connector end
No sequencing
Catheter
1
of
1
Edit
Append
Insert
Move
Delete
Actions
Projection
Sequencing
Skip
Loop
Applicator
Auto recognize
Shields
Close
Catheter 1 of 1
Stepsize
2.5
5.0
10.0 mm
Catheter entry
Tip end
Connector end
Add
Delete
Copy
Offset (mm)
0.0


File
Image
Plan
Reconstruction
Dose Distribution
Help
body (1)
target (2)
Slice : 37 of 39
Z(CT) : -5.6
Catheter: 1 of 1
Display
Light Box On/Off
Image
Flip
Rotate
Image Prefs.
Ruler
Catheter reconstruction
Source step
2.5
5.0
10.0 mm
Catheter entry
Tip end
Connector end
No sequencing
Catheter
1
of
1
Edit
Append
Insert
Move
Delete
Actions
Projection
Sequencing
Skip
Loop
Applicator
Auto recognize
Shields
Close
Catheter 1 of 1
Stepsize
2.5
5.0
10.0 mm
Catheter entry
Tip end
Connector end
Add
Delete
Copy
Offset (mm)
0.0


File
Image
Plan
Reconstruction
Dose Distribution
Help
body (1)
seroma (2)
target (3)
Slice : 26 of 83
Z(CT) : -58.0
85 %
90 %
95 %
100 %
110 %
150 %
Display
Light Box On/Off
Graphical optimization
Dwell weights
Dwell times
Cat
Index
Dwell Weight
1 2 5 1.15
2 2 6 1.39
3 2 7 0.83
4 2 8 1.51
5 3 3 0.20
6 3 4 0.11
7 3 5 0.27
8 3 6 0.35
9 4 2 0.00
10 4 3 0.05
11 4 4 0.00
12 4 5 0.26
13 4 6 0.10
14 4 7 0.37
Maximum
2.66
Global
Local
Reset all
Undo
Redo
INFO: Drag isodose lines with left mouse button.
Ok
Cancel
INFO: Drag isodose lines with left mouse button.


seroma (1)
body (2)
target (3)
Slice : 26 of 54
Z(CT) : 40.3
85 %
90 %
95 %
100 %
110 %
150 %
19
23
1
18
3
22
A
R
L
P
Catheter: 1 of 25

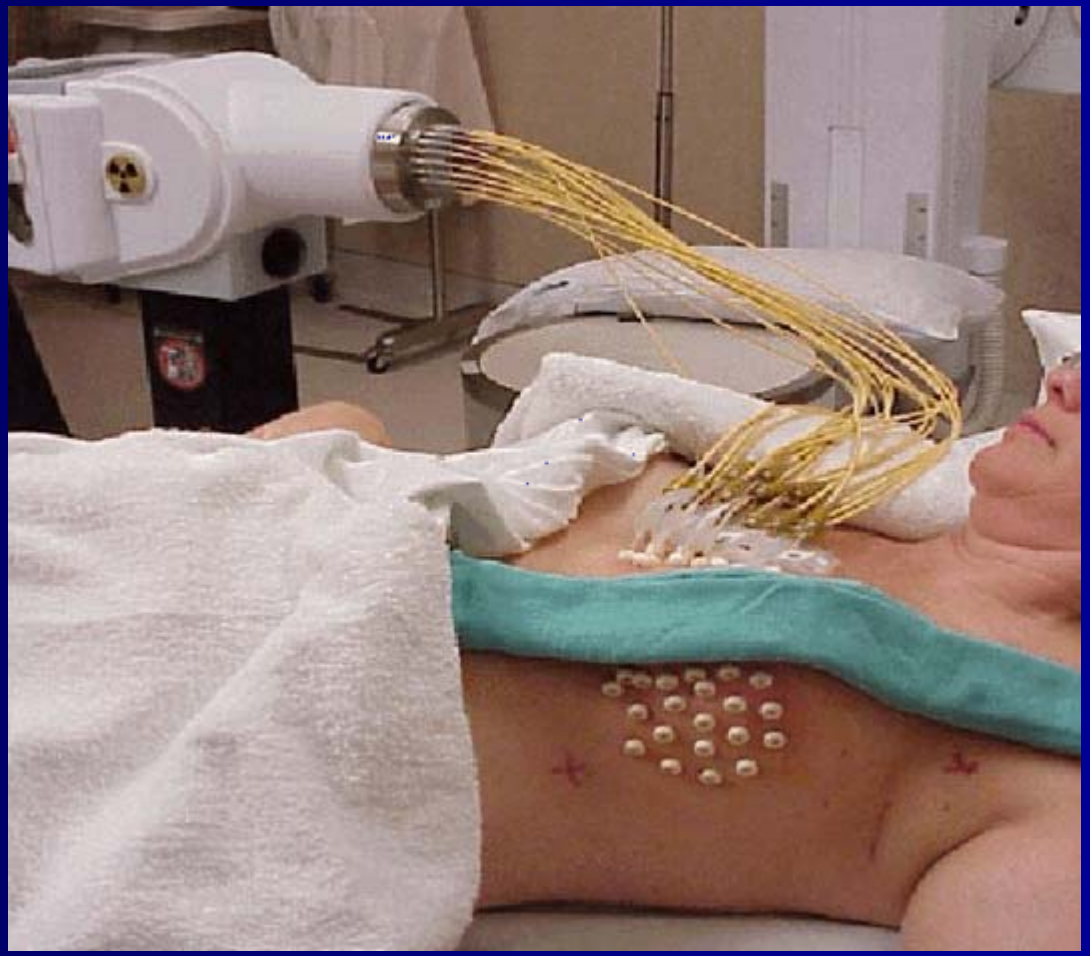

AdGif - UNREGISTERED
85 %
90 %
95 %
100 %
150 %
2
24


3D
Y
25
8
24
23
20
22
19
7
21
18
15
17
14
6
16
13
5
4
12
10
3
11
1
9
2
Applicator

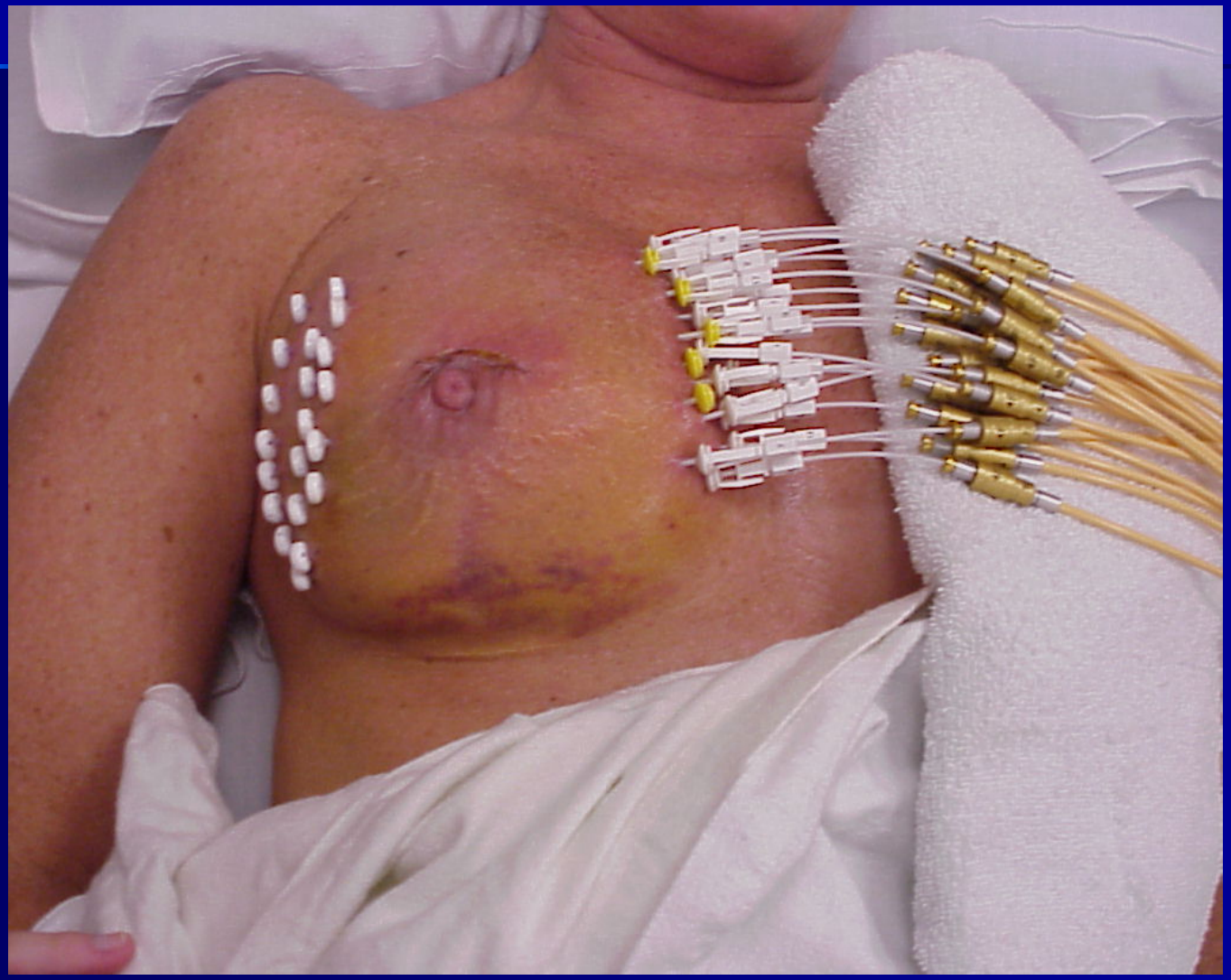
Dosimetric Comparison

	2D Treatment Planning	3D Treatment Planning
R_x	400 cGy	400 cGy
Target Volume	70 cc	70 cc
Total catheters used	21	16
Target volume covered	87%	94%
Total volume by 50%	403 cc	252 cc
Total volume by 100%	140 cc	103 cc
Total volume by 150%	27 cc	30 cc
Dose Homogeneity Index	0.81	0.71

Patient Treatment Position



Comfort Catheter system



Quality Assurance

- Manual Verification of HDR Computer Calculations

Vol (cm^3)	mRaEqhr /1000R*	R_v (Cis/Gy)
50	463	314
80	633	429
100	735	498
140	920	624
180	1087	737
220	1243	843
300	1529	1037
340	1662	1127
380	1788	1212

*** Parker: A dosage system for interstitial Radium Therapy**
BJR:11:313-339, 1938

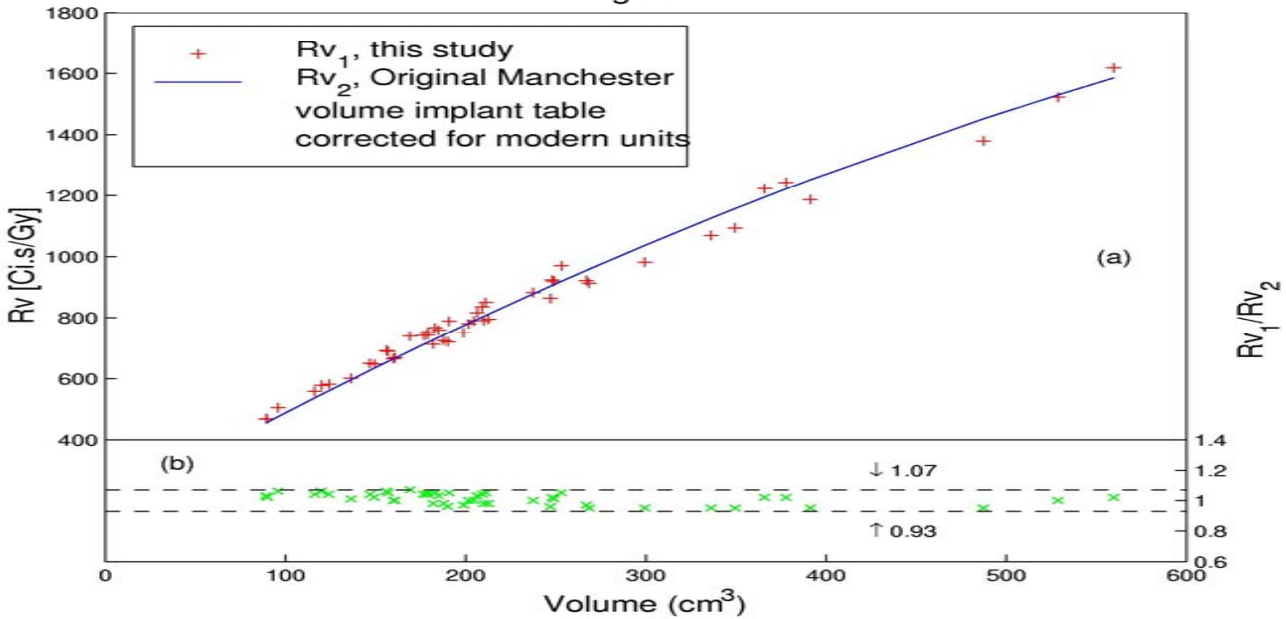
Elongation Factor

Length/ Diameter	Correction Factor
1.5	1.03
2.0	1.06
2.5	1.10
3.0	1.15

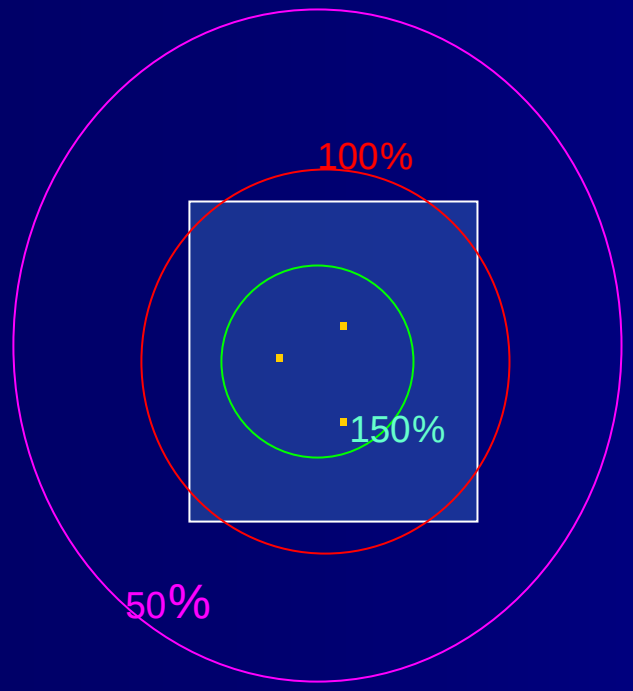
Total Time for volume implants

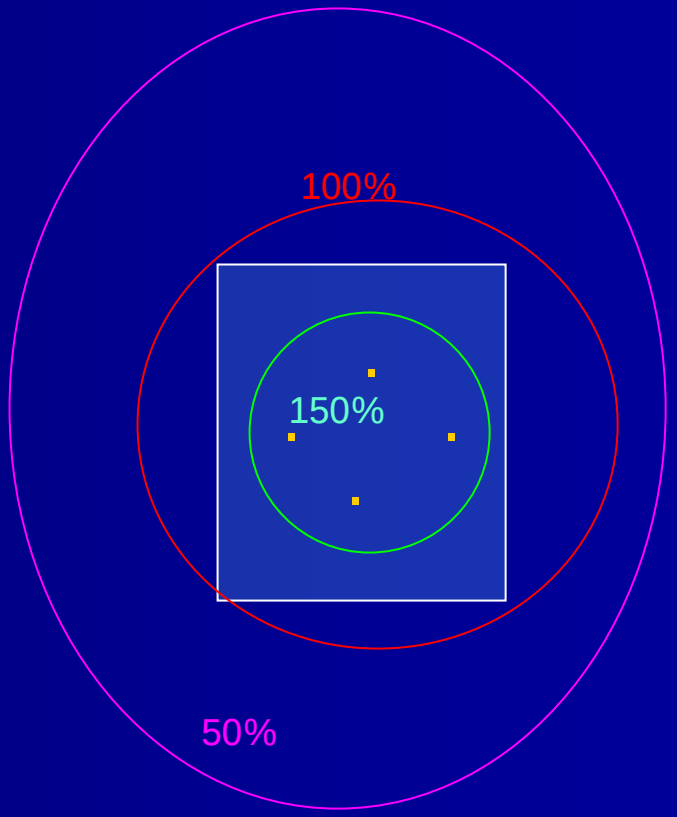
$$\text{Time} = \frac{\text{Reference Dose (Gy)} * R_V * \text{Elongation Factor}}{\text{Activity (Ci)}}$$

Figure 1


Rv$_1$, this study
Rv$_2$, Original Manchester volume implant table corrected for modern units
(a)
(b)
↓ 1.07
↑ 0.93
Rv [Ci.s/Gy]
Rv$_1$/Rv$_2$
Volume (cm^3)
1800
1600
1400
1200
1000
800
600
400
1.4
1.2
1
0.8
0.6
0
100
200
300
400
500
600

Characteristics of Interstitial Implants





Quantitative Analysis of Brachytherapy Implants

- Percent Target Volume Coverage.

  The 100% isodose (Rx) line should cover the whole target.

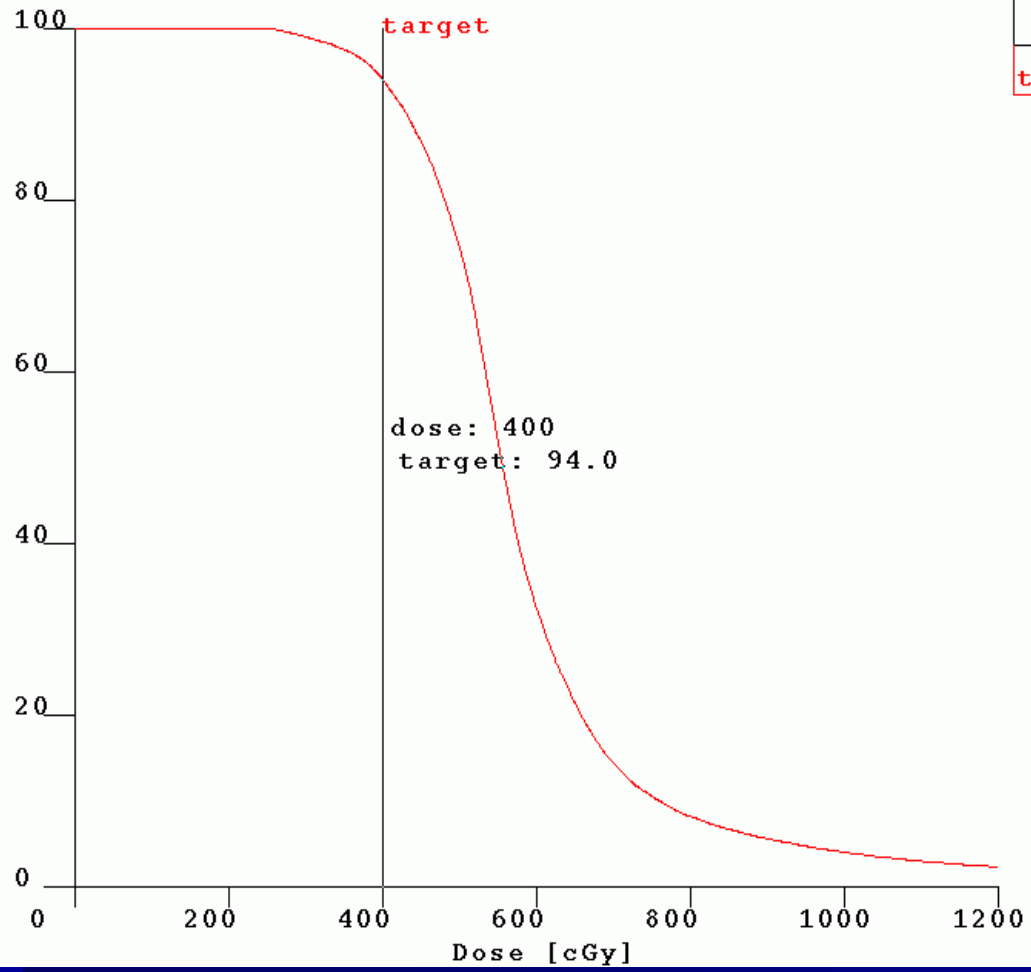
  - Goal 100%.

3D CT Planning

Dose Volume Histogram
(Integral)

Dose displayed:
Brachy total dose in water

Volume [%] # of points: 100000
Max. Dose [cGy]: 1200



VOI	Vol. (cc)	Area (%)	Dose (cGy) Max	Min	Avg.
target	70.1	48	4705	227	598

Quantitative Analysis of Interstitial Implants

- Dose Homogeneity Index (DHI)

$$\mathbf{DHI} = \frac{V_{100} - V_{150}}{V_{100}}$$

- Ideal: DHI = 1.0

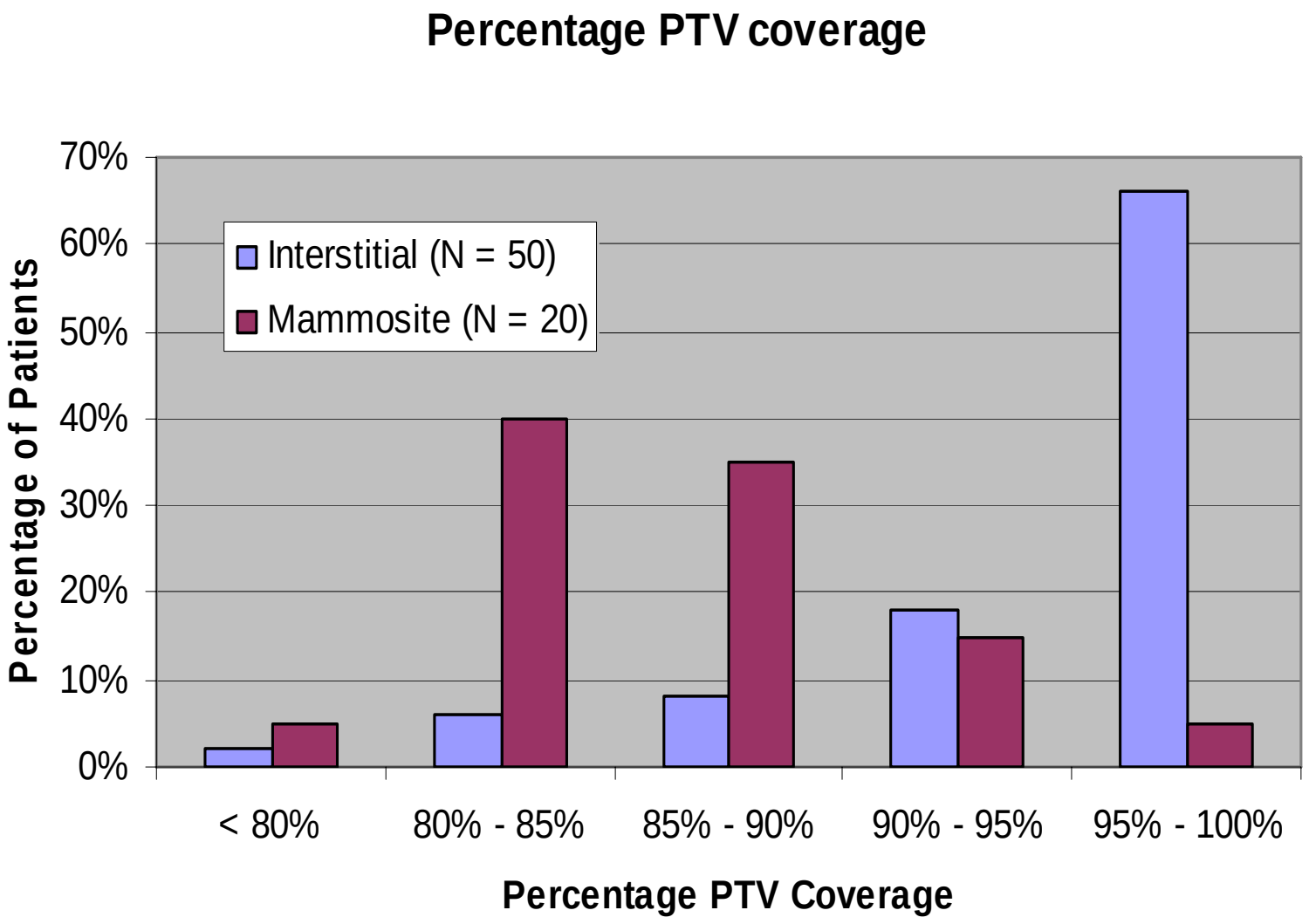
Quantitative Analysis of Interstitial Implants

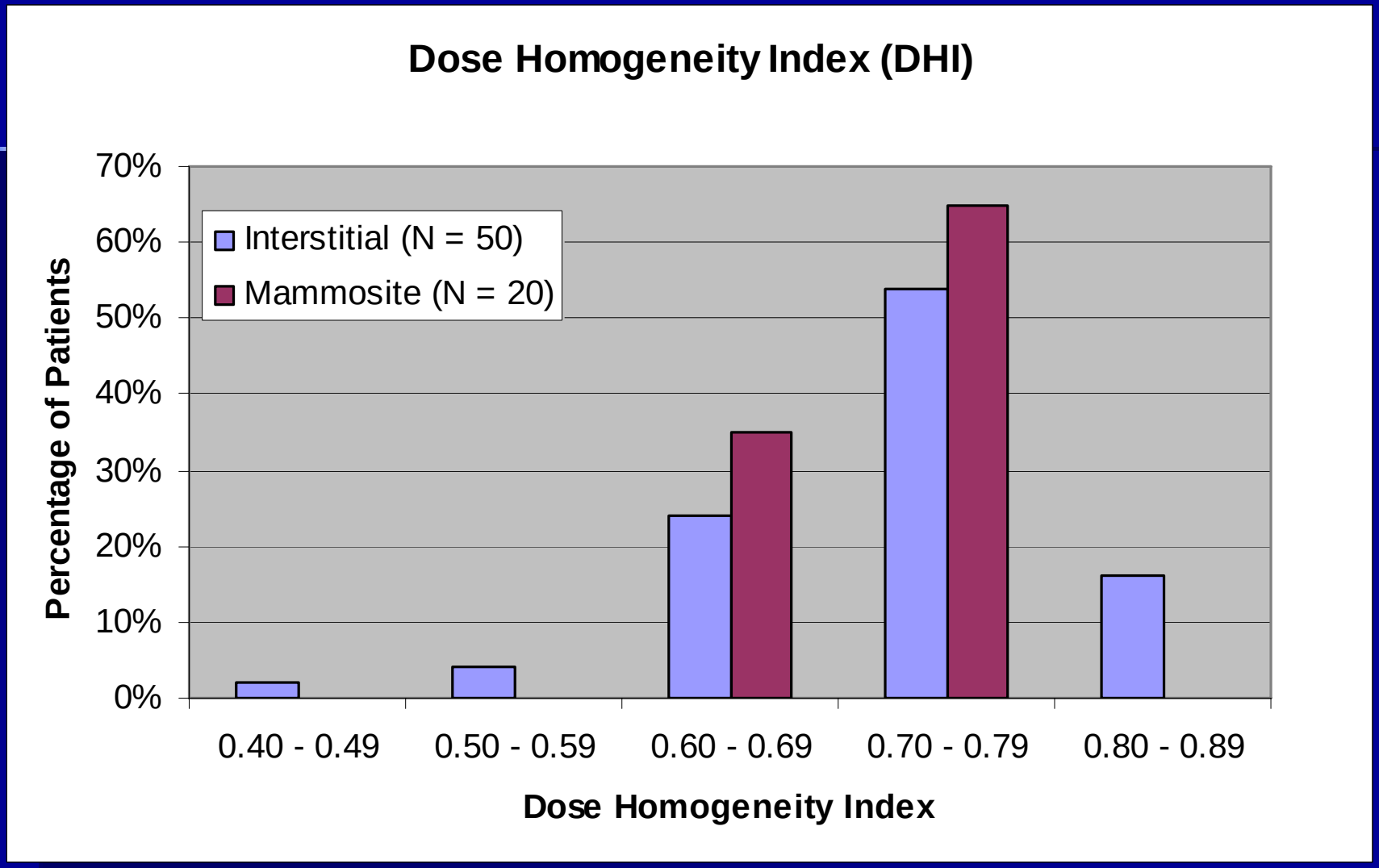
- Ratio of Target Volume to V_{100}

$$\frac{\text{Target Volume}}{\text{Volume of 100\% isodose line}}$$

- Ideal: 1.0

Dosimetric comparison of interstitial and mammosite APBI


Percentage PTV coverage
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of Patients
Interstitial (N = 50)
Mammosite (N = 20)
< 80%
80% - 85%
85% - 90%
90% - 95%
95% - 100%
Percentage PTV Coverage


Dose Homogeneity Index (DHI)
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of Patients
Interstitial (N = 50)
Mammosite (N = 20)
0.40 - 0.49
0.50 - 0.59
0.60 - 0.69
0.70 - 0.79
0.80 - 0.89
Dose Homogeneity Index

Institutional dosimetric comparison of APBIs

	V100 (cm^3)		V150 (cm^3)		PTV (cm^3)		% PTV coverage	
	This study	WBG	This study	WBG	This study	WBG	This study	WBG
Mammosite	74	87	21	20	86	81	86	76
Interstitial	226	186	59	24	182	105	95	58

Conclusions

Image guided breast brachytherapy challenges the notion that the entire breast needs to be irradiated…

Conclusions

…and offers an attractive alternative to 6 weeks of daily external beam radiation therapy for a heterogeneous population of women with early stage breast cancer.

Acknowledgments

- Heath Odau, M.S.
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