Hello…

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5TH BBCC
BANGLADESH BREAST CANCER CONFERENCE 2025

AI Driven Auto Contouring and Planning for Breast Cancer Radiotherapy: A Feasibility Study on Geometric and Dosimetric Accuracy

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EBRT Workflow

Diagnosis

↓

Immobilization and imaging

↓

Tumor and organ contouring

↓

Treatment plan generation

↓

Treatment plan verification

↓

Patient Treatment

Introduction

- Quality of EBRT treatment planning depends on:
  - Target coverage
  - Normal tissue sparing
- One of the main challenges in EBRT:
  - Accurate and efficient contouring and Planning
- Workload
  - About 10 million new diagnoses each year globally
  - Many of cases need re-contouring during the treatment

Workload effects quality of Radiation Therapy

Introduction (cont.)

Manual Contouring

- **Radiation oncologists create structure sets**
  - **Based on anatomical and/or functional information**
  - **Following consensus guidelines**

- **Organ sparing and plan optimization depend on:**
  - **Definition and standardization of OARs**
  - **Appropriate consideration of movements**

- **Inter and intra-observer variability in contour delineation is a common issue**
  - **Affect the resulting plan quality**
  - **Patient outcomes**

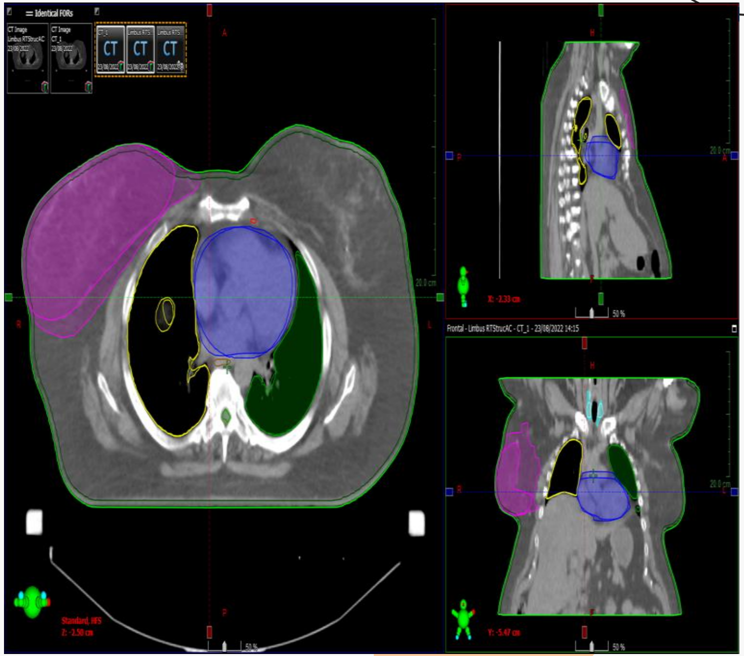

Figure: Structures contouring of Breast case for radiotherapy

Introduction (cont.)

Auto Contouring

A

- Simplest basic approach for auto segmenting CT scans
- A voxel is allocated to a ROI if its Hounsfield units exceeds a predefined threshold value

Intensity Analysis

B

- Place an initial contour or surface close to the ROI to be segmented
- Deform image based on image information, such as intensity gradients, and internal constraints.

Shape Modeling

C

- Use of manually segmented reference image.
- Image registration specifies how a segmented image should be adjusted using mutual information

Atlas Based Auto Segmentation

D

- Unsupervised-learning algorithms may find areas of comparable voxels but cannot name these regions
- Supervised-learning systems requires manually segmented images for image segmentation

Non-deep Machine Learning

Deep Learning

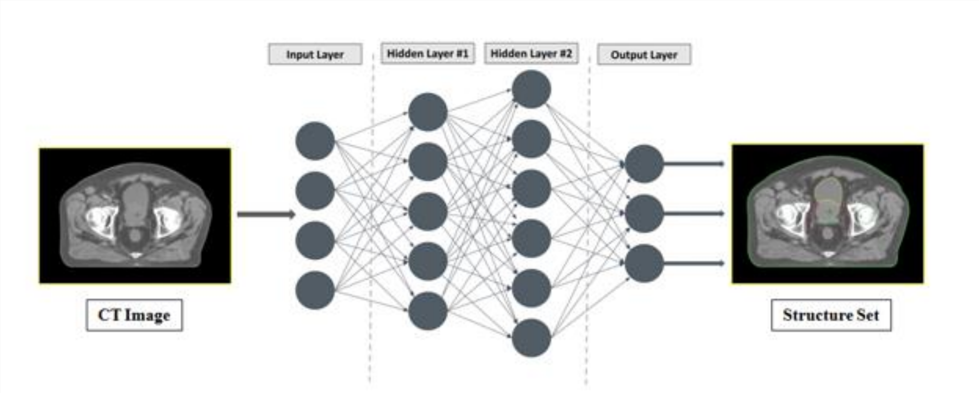

Figure: A simple artificial neural network for anatomy contouring

- Early CNNs were used to segment a two-dimensional image pixel by pixel.
- FCNN, replace the fully connected layers of a CNN with convolutional layers for more effective segmentation.
- Now the U-net CNN architecture is the state-of-the-art auto-contouring method in image contouring.

Helps to minimizes:

- **Variability**
- **Clinical workload**

Automatic contours = Clinically used contour ?

- Evaluation according to literature:

✓ **Geometric metrics** X **Dosimetric metrics**

- But dosimetry performance is influenced :
  - Not only by geometric precision,
  - But also by spatial dose distribution and gradient

- Each dosimetric parameter (i.e., Dmax, Dmean, Dv%) has a distinct reliance and sensitivity to geometric change

Geometric impact into dose domain and plan quality remains elusive.

Aim of the Study

- To measure time savings in anatomy contouring using AI based auto-contouring software
- To gather subjective feedback of physicians on contouring quality of auto-contouring tool
- To quantitatively investigate the quality and accuracy of structure contours generated either wholly and partially by auto-contouring.
- To investigate the dose metrics and quality of radiation therapy treatment plans derived from reviewed auto-contouring structures.
- To evaluate the impact of the variations performed by radiation oncologists starting from the auto-segmentations.

Materials & Methods

Materials

- GE LightSpeed 16 Slice CT simulator
- Auto Contour, v2.5 and EZFluence v2.4.4 Software from RAD formation
- Varian Eclipse v 13.6
- MATLAB program for data analysis
- 20 Breast Cancer Cases
- 3DCRT planning

AutoContour

Version2.5.0 Rev 1.0

EZFluence

V2.4.3

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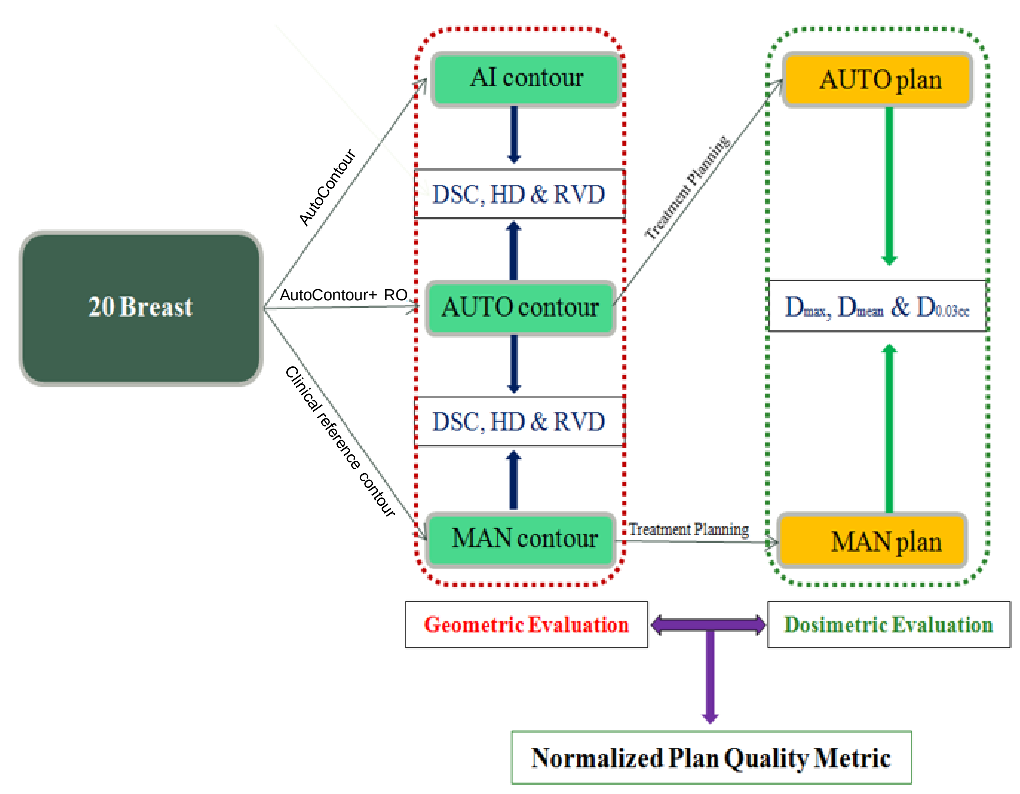
Materials & Methods

Workflow of the Study



Statistical analysis parameters

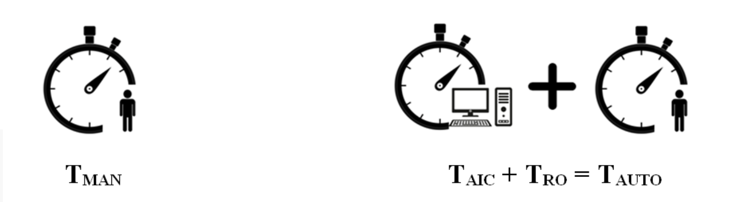
Condition	H_o	Difference
$P > \alpha$	Accept/No reject	No
$P < \alpha$	No accept/Reject	Yes
$- CI < 0 < CI$	Accept/No reject	No

Methods

Time Evaluation

T_{MAN} → Contouring time approximated by physicians with their previous experiences

T_{AUTO} → Auto Contour time (T_{AIC}) together with RO editing times (T_{RO}) including DICOM file export and import time



$$\text{Time savings} = \frac{T_{MAN} - T_{AUTO}}{T_{MAN}}$$

Qualitative Evaluation

Severe Correction : Require correction → Large and obvious errors
Medium Correction : Require correction→ Minor errors that need a small amount of editing
Slight Correction : Accepted→ Minor errors but these are clinically not significant
No Correction : Accepted→ Contour is very precise

Geometric Evaluation

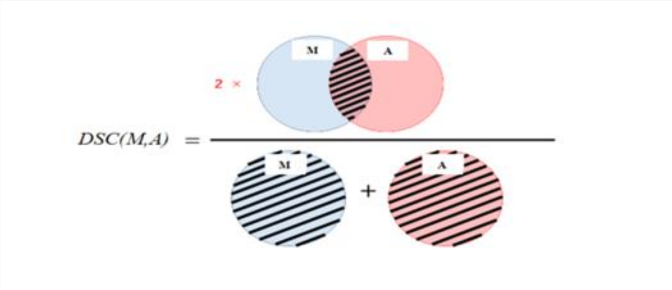
Dice Similarity Coefficient

- A measure of the volumetric overlap of two contours of a structure

No overlay → 0

Total overlay → 1

$$DSC(M,A) = \frac{2|M \cap A|}{|M| + |A|}$$



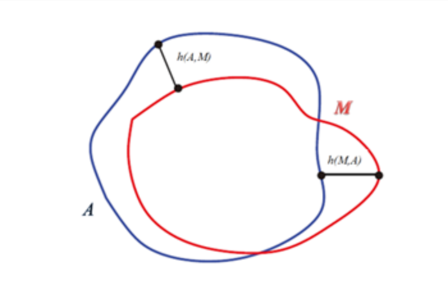
Hausdorff Distance

- A bi-directional measure of distance between two contour surfaces

No overlay → > 1 mm

Total overlay → 0 mm

$$HD(M,A) = \max\,[h(M,A), h(A,M)]$$



Relative Volume Difference

- Absolute size difference between the regions in terms of reference size

No overlay → 1 and more

Total overlay → 0

$$RVD = \left|\frac{|A| - |M|}{|M|}\right|$$

Dosimetric Evaluation

OAR Dose Metrics

- For generic description : Integrated D_{max}, D_{mean} and also $D_{0.03cc}$ in terms of absolute dose

$$\Delta D_X = \frac{(D_X)_{AUTO} - (D_X)_{MAN}}{(D_X)_{MAN}}$$

- Serial organs → D_{max} and D_{mean}
- Parallel organs → D_{mean} and/or $D_{x\%}$

D_X → D_{max}, D_{mean} or $D_{0.03cc}$

PTV Dose Metrics

- Homogeneity Index (HI): to evaluate the dose uniformity within the PTV

$$\Delta HI = \frac{|HI_{AUTO} - HI_{MAN}|}{|HI_{MAN}|}$$

Where, $$HI = \frac{(D_{2\%} - D_{98\%})}{D_{50\%}}$$

- Conformity Index (CI): to obtain a quantitative evaluation of the PTV coverage by the prescribed dose

$$\Delta CI = \frac{|CI_{AUTO} - CI_{MAN}|}{|CI_{MAN}|}$$

Where, $$CI = \frac{(TV_{PV})^2}{V_{PTV} \times V_{TV}}$$

Normalized Plan Quality Metric

- nPQM works as a hypothetical **virtual physician**

$$nPQM = \frac{PQM}{PQM_{max}} \times 100$$

❑ Threshold Score:

- No points → objective is not achieved
- Maximum points → accomplished objective

❑ Linear Score:

- No points → does not exceed the “minimally acceptable threshold”
- Maximum points → satisfies the constraint's “ideal threshold”
- Linear interpolated score → between the two thresholds

Plan quality metric for evaluation of treatment plans:

Structure	Constraint	Function	Thresholds	Max Score
PTV	D99%	Linear	>6000 cGY (100%) ; >5700cGy (95%)	5 ; 4
	D0.1 cc	Linear	<6300cGy(105%) ; <6420cGy(107%)	5 ; 4
Rectum	V4500 cGy	Threshold	<15%	3
	V2800 cGy	Threshold	<35%	3
	V900 cGy	Threshold	<80%	3
Bladder	V4500 cGy	Threshold	<25%	3
	V2800 cGy	Threshold	<50%	3
Anal Canal	V4500 cGy	Threshold	<15%	3
	V2800 cGy	Threshold	<35%	3
	V900 cGy	Threshold	<80%	3
Femur Right	V3500 cGy	Threshold	<1%	2
Femur Left	V3500 cGy	Threshold	<1%	2

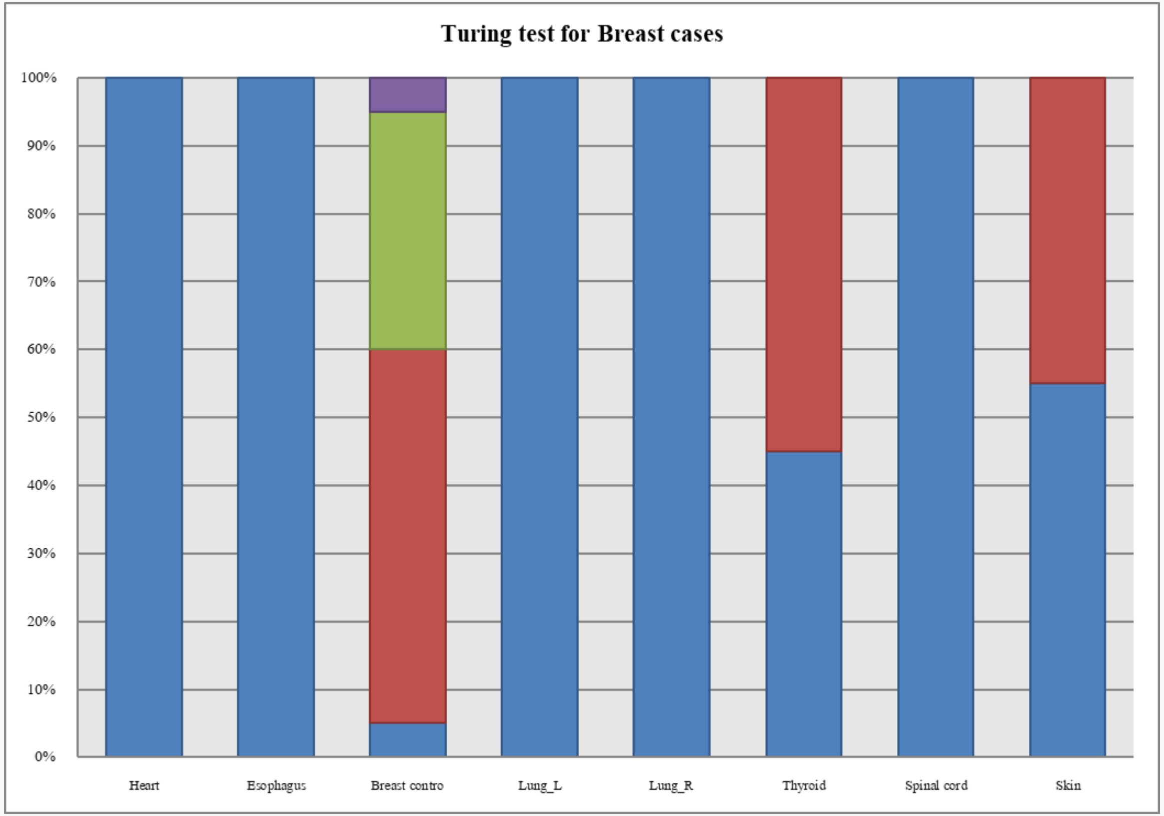
Results & Discussions

Time Savings

Procedure	T_{MAN}(avg)	T_{AUTO}(avg)	Time Savings	Saved Time (%)
Contouring	28 min	9.8 min	18.2 min	**65%**
Planning	40 min	10.9 min	29.1 min	**73%**

- ❑ More than 65% of contouring time can be saved.
- ❑ More time saving is possible by implementing a fully integrated system.

Qualitative Evaluation



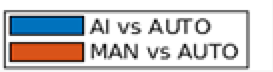
Breast:

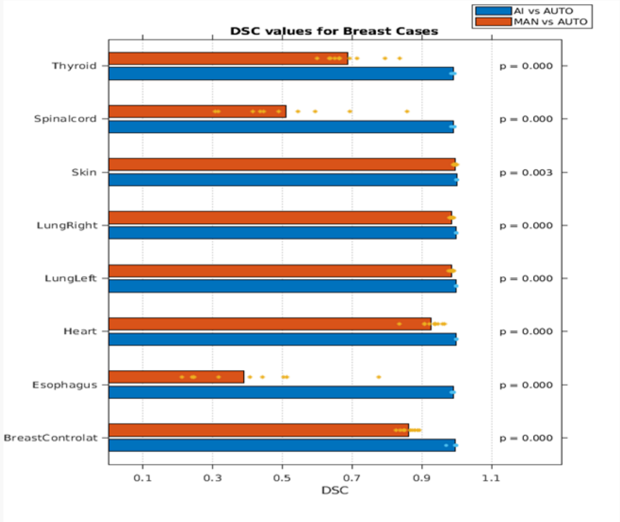
No correction

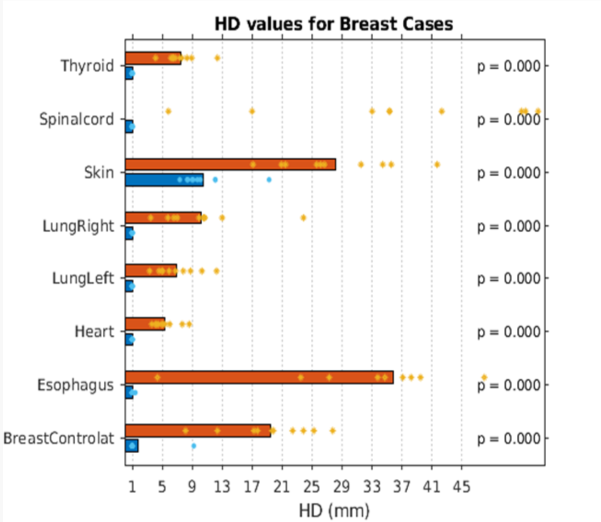
Accepted → 95%

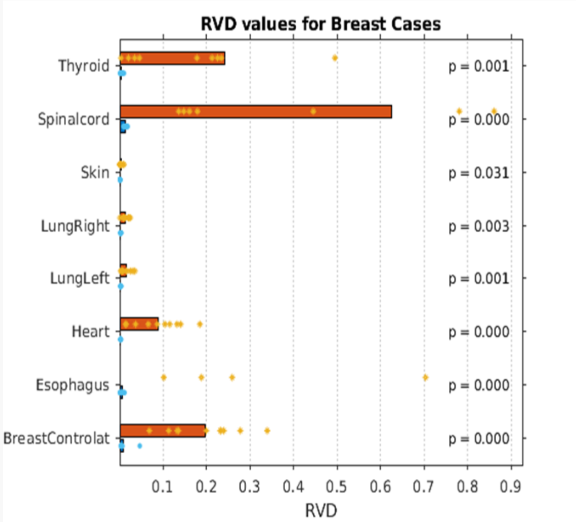
Corrected → 5%

Geometric Comparison (Breast)





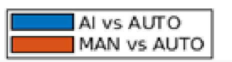


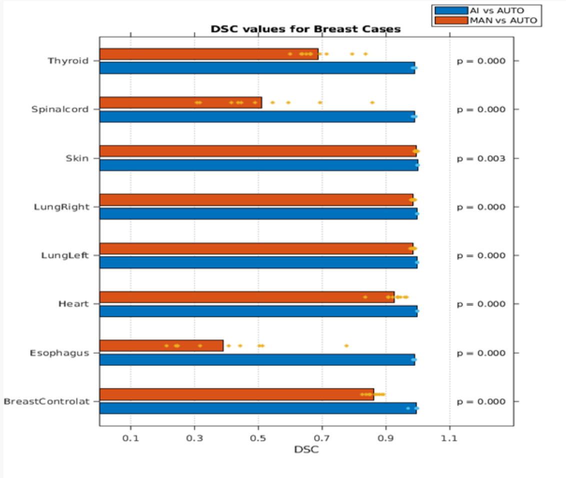


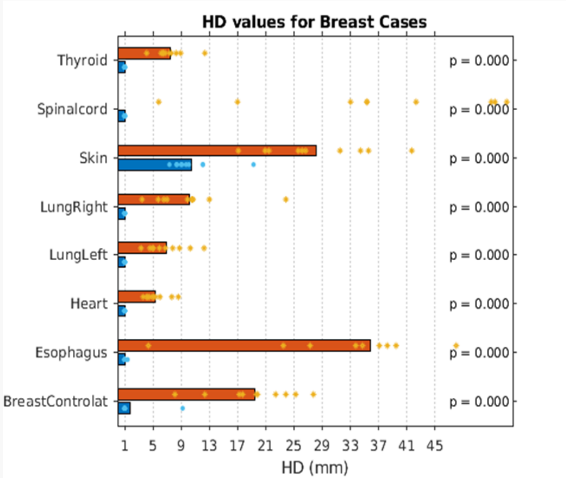
AI vs AUTO:

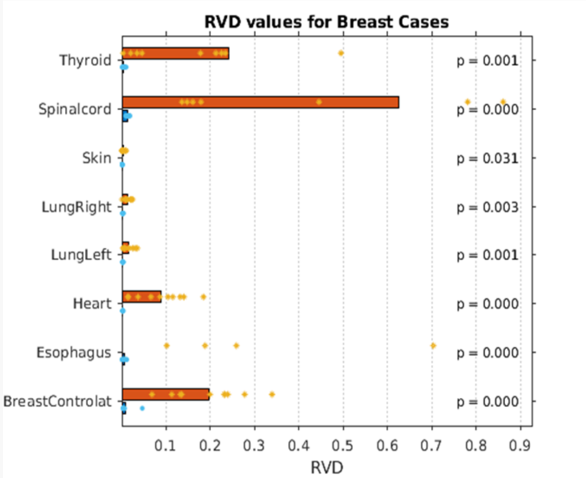
- More than 95% similarity
- Skin showed upto 12 mm HD
- Almost no volume difference

Geometric Comparison (Breast)







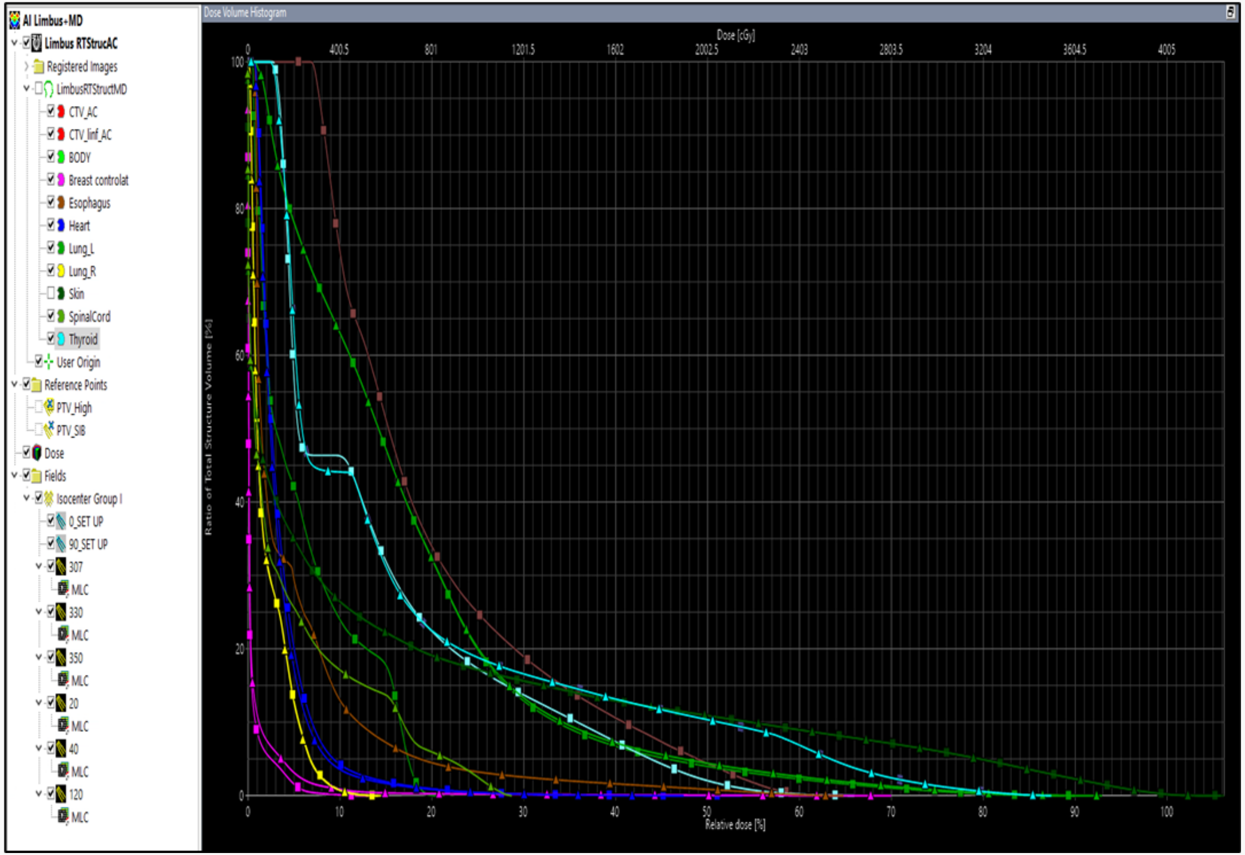


AI vs AUTO:

- More than 95% similarity
- Skin showed upto 12 mm HD
- Almost no volume difference

MAN vs AUTO:

- Spinal cord → DSC<0.50 & 61% RVD
- Contralateral breast →20% volume difference
- Thyroid→ 69% DSC & 24% RVD
- High HD: Esophagus, contralateral breast and skin



Breast : DVH for MAN & AUTO contours

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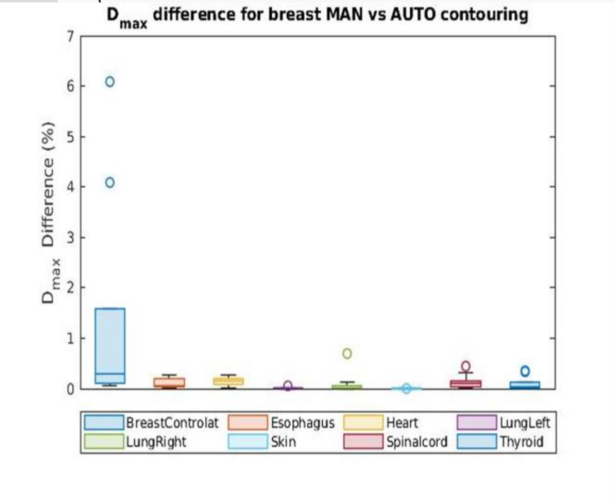
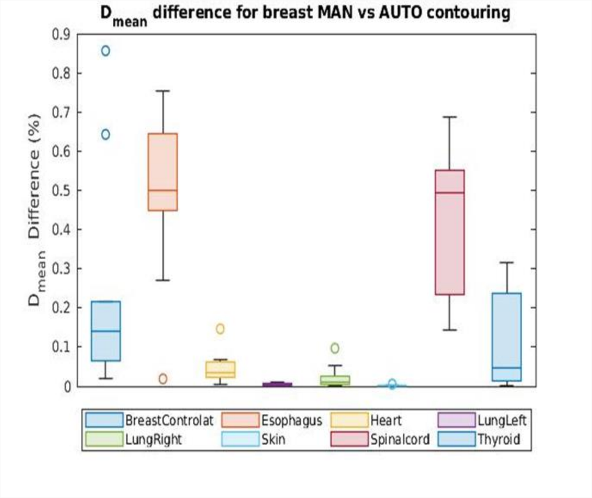
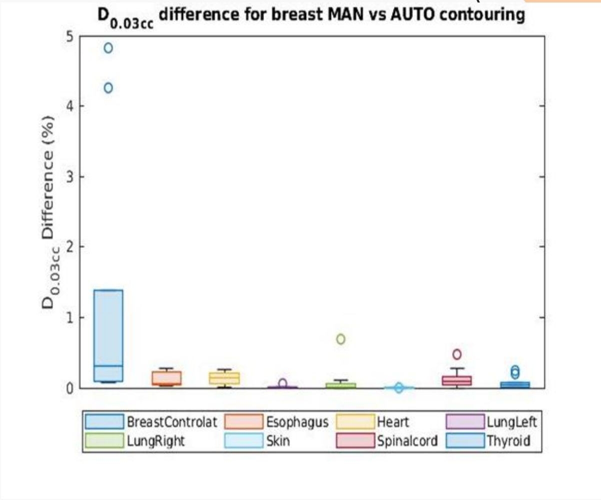
Structural contours has influence on:

- Plan optimization
- Plan assessment
- Decision-making process for plans

Dosimetric Comparison (Breast)







ΔDmax

- Contralateral Breast: 30%
- Spinal cord: 12%
- Heart: 14%

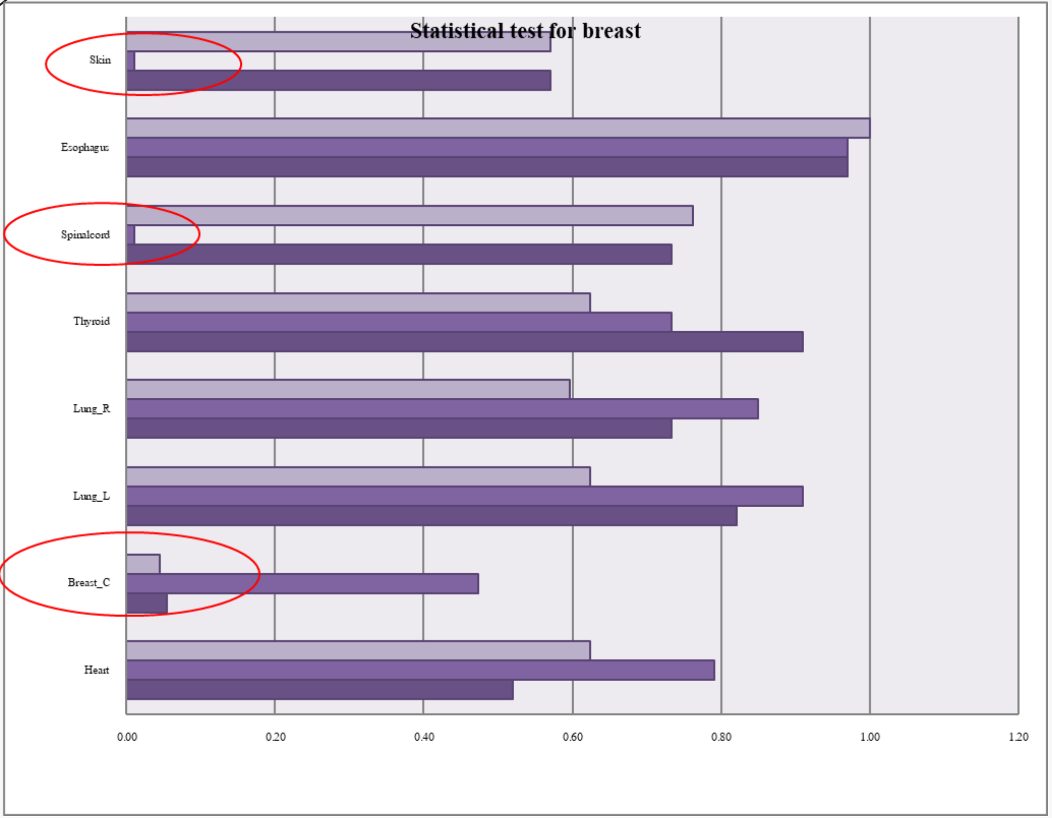
ΔDmean

- Contralateral Breast : 14%
- Spinal cord: 49%
- Esophagus : 49%

ΔD0.03cc

- Contralateral Breast: 31%
- Spinal cord: 10%
- Heart: 14%

Statistical Analysis



None of the OAR dose has been found to be statistically significant ($p \geq 0.05$) except the following:

Breast:

Contralateral Breast,

$D_{0.03cc}$→ $p = 0.045$

Spinal cord & Skin,

D_{mean}→ $p = 0.011$

Geometry vs Dosimetry

Study Site	OAR	DSC	HD	RVD	Dmax	Dmean	D0.03
Breast	Breast Contralat	0.87	19.75	0.22	0.30	0.14	0.31
	Heart	0.94	5.00	0.09	0.14	0.03	0.14
	Thyroid	0.66	7.03	0.19	0.04	0.05	0.04
	Spinal Cord	0.47	35.34	0.61	0.12	0.49	0.10
	Esophagus	0.36	35.91	1.22	0.06	0.50	0.06

Yellow → Significant Difference

Red → Higher Difference

Geometry vs Dosimetry

Study Site	OAR	DSC	HD	RVD	Dmax	Dmean	D0.03
Breast	Breast Contralat	0.87	19.75	0.22	0.30	0.14	0.31
	Heart	0.94	5.00	0.09	0.14	0.03	0.14
	Thyroid	0.66	7.03	0.19	0.04	0.05	0.04
	Spinal Cord	0.47	35.34	0.61	0.12	0.49	0.10
	Esophagus	0.36	35.91	1.22	0.06	0.50	0.06

Yellow → Significant Difference

Red → Higher Difference

Normalized Plan Quality Metric

Study Site	Mean (SD)	Median (Range)
Breast	0.077 (0.160)	**0.000** (0.00-0.500)

- nPQM as a virtual physician
- Integrates both geometry and dosimetry assessment.

Plan Quality Difference

- Breast: 0%

Conclusions

- Although auto-contouring system achieved state-of-the-art geometrical and dosimterical performance, human review is still unavoidable
- AI driven auto contouring would be improvement to speed up the contouring process over present clinical practice.
- Plans based on automatically generated contours do not overdose nearby OARs
- AI based auto-contouring may help to establish a standard starting point for radiation therapy treatment.
- This study offers a proof-of-concept methodology to investigate the impact of including an auto-contouring and planning software in the RT workflow.

Thanks!

Do you have any questions?

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