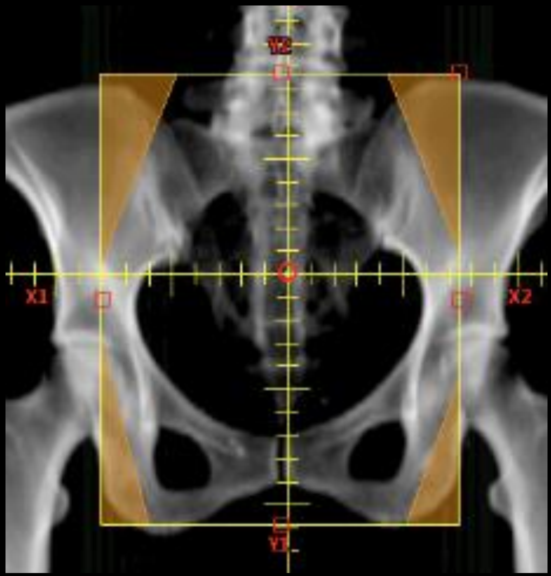
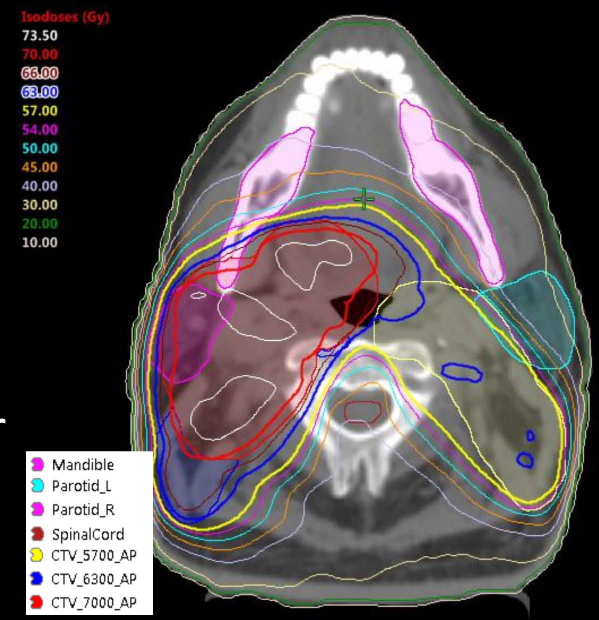
The Radiation Planning Assistant (RPA) for Radiation Therapy Planning in Low- and Middle-Income Countries



Laurence Court PhD

University of Texas

MD Anderson Cancer Center



- Automated treatment planning (Radiation Planning Assistant) - Introduction
- Workflow example / demo – cervical cancer
- Automated treatment planning for head/neck cancer patients
- Deployment

Conflicts of Interest

- Funded by NCI UH2 CA202665
- Equipment and technical support provided by:
  - Varian Medical Systems
  - Mobius Medical Systems

- Other, not related projects funded by NCI, CPRIT, Varian, Elekta

MD Anderson Cancer Center, Houston

- Laurence Court, PhD - PI
- Beth Beadle, MD/PhD - PI
- Joy Zhang, PhD – algorithms and integration
- Peter Balter, PhD – radiation physics
- Jinzhong Yang, PhD - atlas segmentation
- Ryan Williamson, MS – software tools
- Rachel McCarroll – H&N algorithms
- Kelly Kisling, MS – GYN, breast algorithms
- Ann Klopp, MD/PhD – GYN planning
- Anuja Jhingram, MD – GYN planning
- David Followill, PhD – audits/deployment
- James Kanke and dosimetry team

Commercial Partners

- Varian Medical Systems (providing 10 Eclipse boxes for UH2 phase + API technical support)
- Mobius Medical Systems (providing 10 Mobius boxes for UH2 phase)

Primary Global Partners

- Santo Tomas University, Manila
  - Michael Mejia, MD
  - Maureen Bojador, MS (physics)
  - Teresa Sy Ortin, MD
- Stellenbosch University, Cape Town
  - Hannah Simonds, MD
  - Monique Du Toit – physics
  - Vikash Sewram, PhD

Global testing sites

- University of Cape Town
  - Hester Berger, PhD
  - Jeannette Parkes, MD
- University of the Free State
  - William Rae, PhD
  - William Shaw, PhD
  - Alicia Sherriff, MD
- 4 additional centers in South Africa & The Philippines

Staff shortages

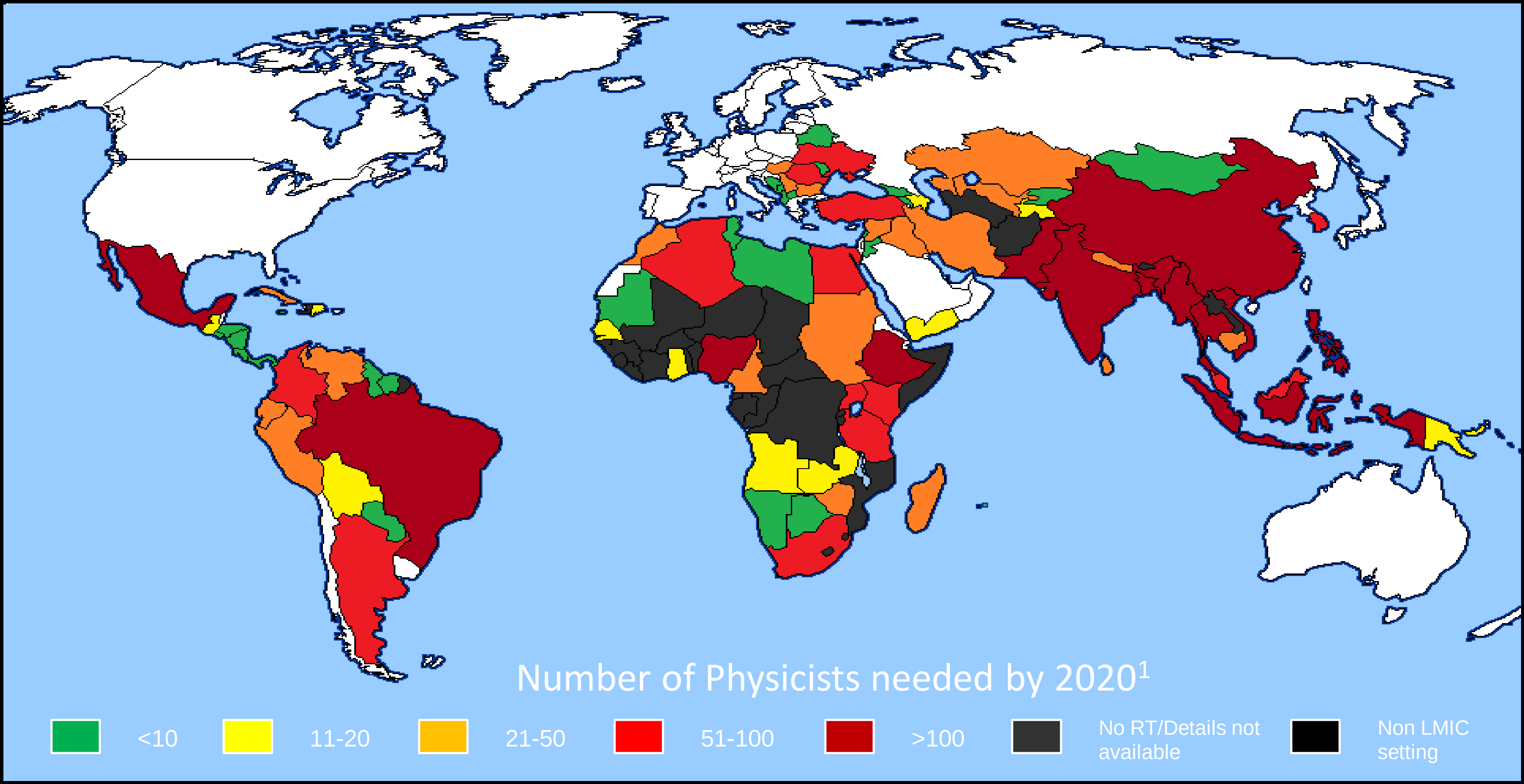


Figure by Rachel McCarroll, based on data in *Datta NR, Samiei M, Bodis S. Radiation Therapy Infrastructure and Human Resources in Low- and Middle-Income Countries: Present Status and Projections for 2020. International Journal of Radiation Oncology*Biology*Physics. 2014;89(3):448-57.*

Motivation for automated planning 1: Staff shortages

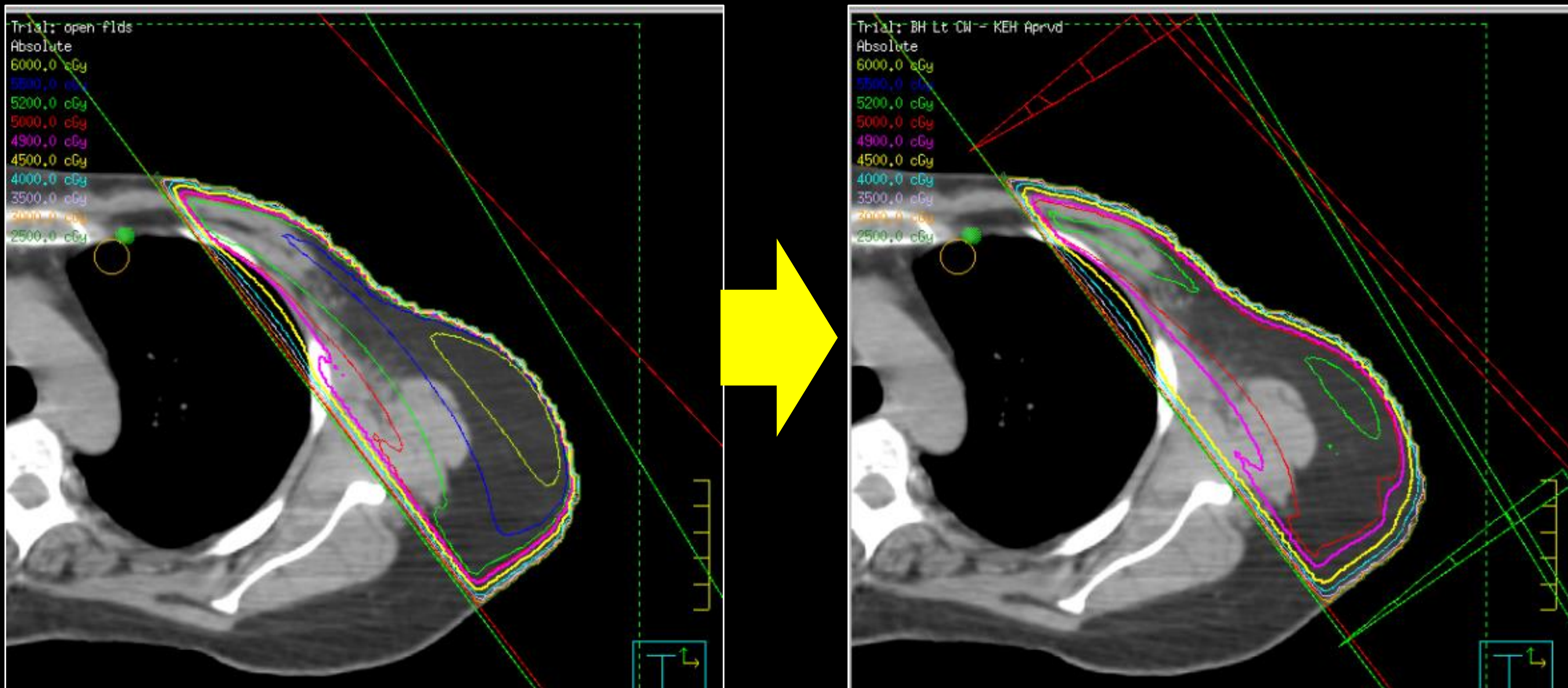
Country	Additional number of radiotherapy infrastructure and staffing required by 2020			
	Treatment units	Radiation oncologists	Medical physicists	Radiation therapy technologists
Philippines	140	141	133	382
South Africa	56	93	82	82
All LMI regions	9169	12,147	9,915	29,140

*Datta NR, Samiei M, Bodis S. Radiation Therapy Infrastructure and Human Resources in Low- and Middle-Income Countries: Present Status and Projections for 2020. International Journal of Radiation Oncology*Biology*Physics. 2014;89(3):448-57.*

- Large deficit in resources – including medical physicists and technologists
- Staff retention is also a problem (anecdotal)
- Many international guidelines suggest that medical physicists need 2+ years residency, typically following graduate school – so 4+ years per person.
- Approximately 50% of physicist time is spent doing treatment planning
- If planning was automated, then the deficit of medical physicists could be reduced to ~5000.

Motivation 2: 3D planning

- All our partner institutions are treating chest walls using standard opposed oblique open fields (i.e. not optimized for the individual patient's geometry)
- Automated planning could change this



Comparison of the dose distribution for a chest wall treatment with optimized wedges (right) and with open fields (left). The non-optimized plan has a large region of soft tissue receiving 60Gy (6000cGy), compared with 52Gy (5200cGy) in the optimized plan.

Specific goals of the Radiotherapy Planning Assistant (RPA)

- Automatically create high quality radiation plans for cancers of the:
  - Uterine Cervix
  - Breast (intact and chest wall)
  - Head and neck (nasopharynx, oropharynx, oral cavity, larynx, etc.)
- Generate treatment plans that are:
  - Generated from scratch (including transfer to the local machine) in less than 30 minutes.
  - Compatible with all treatment units and record-and-verify systems.
  - Internally QA'd in an automated fashion within the system.
- Limit need for the radiation oncology physician to:
  - Delineate the target (location).
  - Provide the radiation prescription.
  - Approve the final plan.
- Create a system that can be used by an individual with:
  - A high school education.
  - ½ day of training (online and video) on the RPA itself.

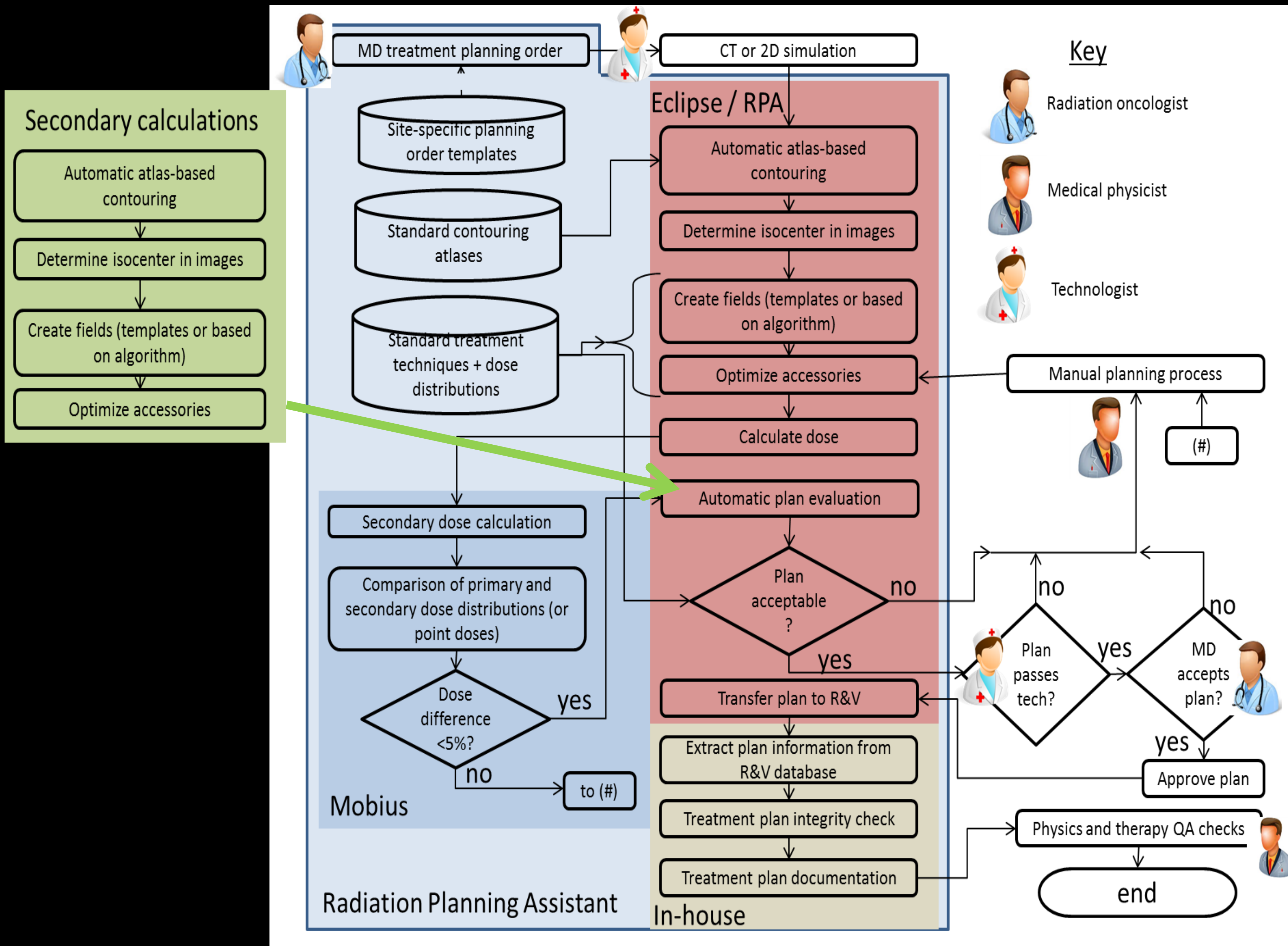
RPA project schedule – from NCI UH2/UH3 mechanism

Phase 1 (UH2): Development Phase – 2 years – to April 2018

- System development at MDACC
- Local testing at Santo Tomas (Manila) and Stellenbosch (Cape Town) [MDACC sister institutions]
- Additional testing at other centers in The Philippines, South Africa

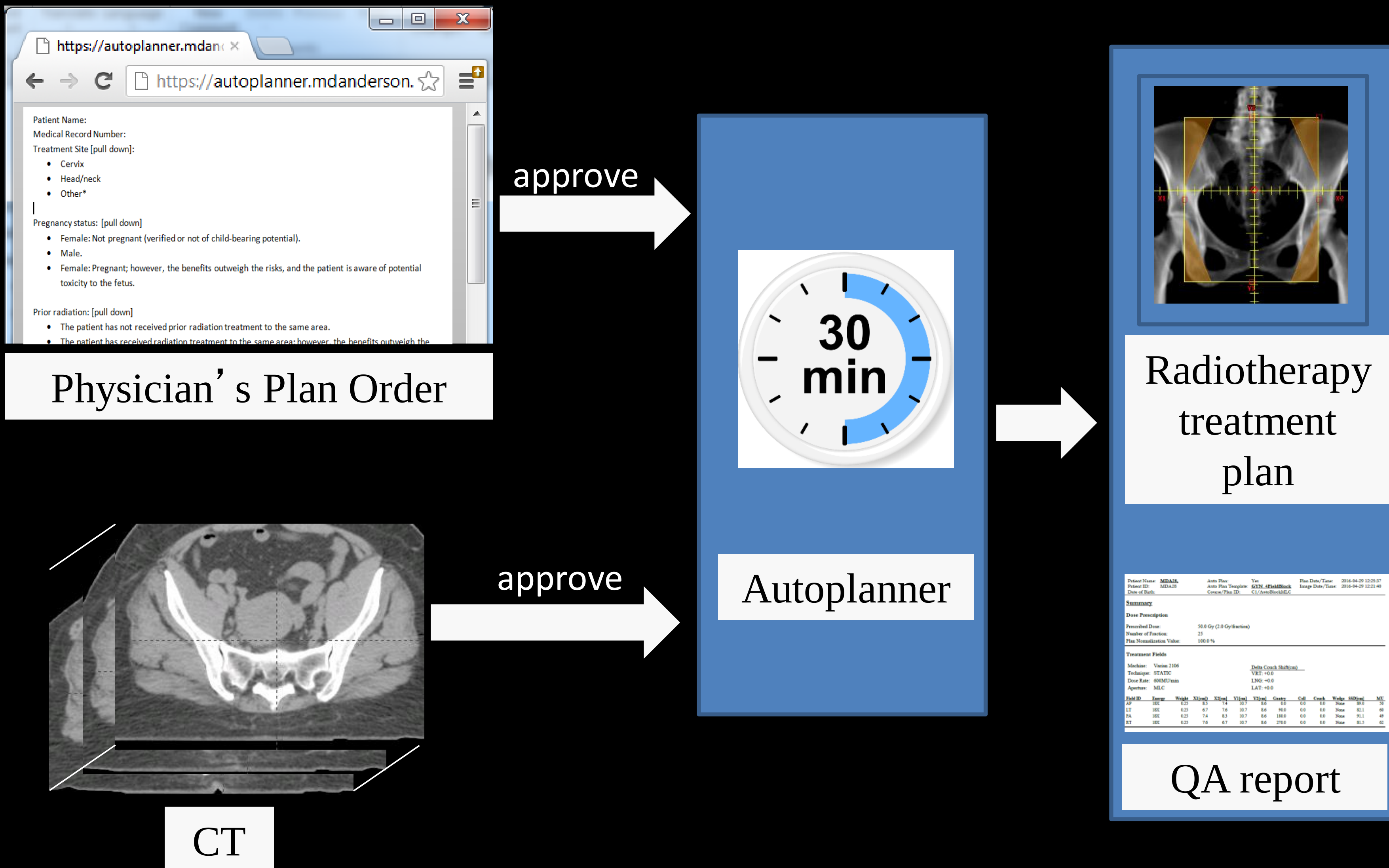
Phase 2 (UH3): Validation Phase – 3 years

- Full patient testing (same centers, 12 months)
- Then other centers across Southeast Asia and Sub-Saharan Africa

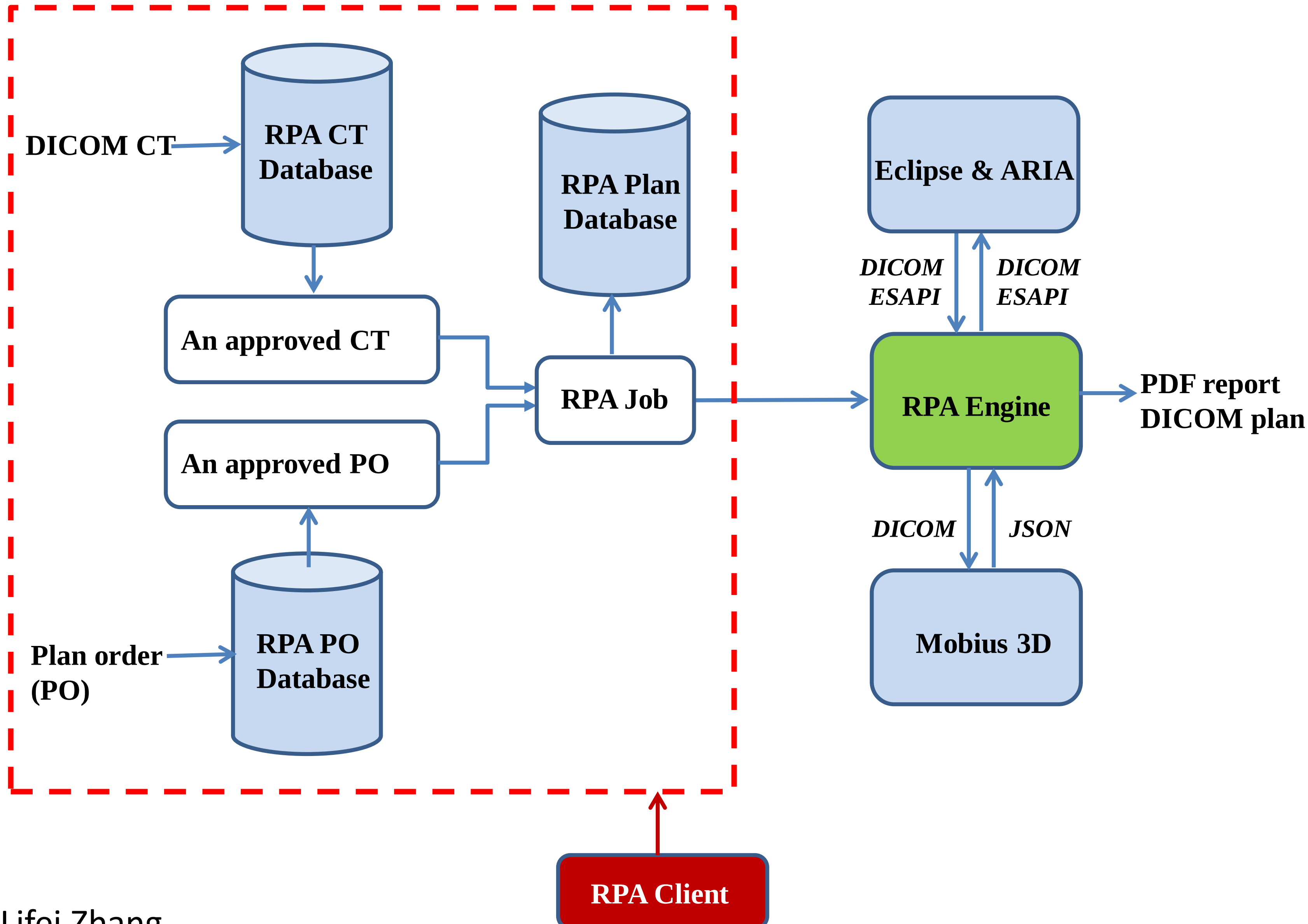


Secondary calculations
Automatic atlas-based contouring
Determine isocenter in images
Create fields (templates or based on algorithm)
Optimize accessories
MD treatment planning order
Site-specific planning order templates
Standard contouring atlases
Standard treatment techniques + dose distributions
CT or 2D simulation
Eclipse / RPA
Automatic atlas-based contouring
Determine isocenter in images
Create fields (templates or based on algorithm)
Optimize accessories
Calculate dose
Automatic plan evaluation
Plan acceptable ?
no
yes
Transfer plan to R&V
Extract plan information from R&V database
Treatment plan integrity check
Treatment plan documentation
In-house
Secondary dose calculation
Comparison of primary and secondary dose distributions (or point doses)
Dose difference <5%?
yes
no
to (#)
Mobius
Radiation Planning Assistant
Key
Radiation oncologist
Medical physicist
Technologist
Manual planning process
(#)
no
Plan passes tech?
yes
no
MD accepts plan?
yes
Approve plan
Physics and therapy QA checks
end

Workflow overview (user's perspective)



Big Picture of RPA 2.0 Workflow



Lifei Zhang

WORKFLOW EXAMPLE: CERVICAL CANCER

Name: test
MRN: MDA11
Site: Cervix
Date: 12/8/2016 12:55:13 PM
Comment:

General Questions

Sex/Pregnancy status:	☑ Female: Not pregnant (verified or not of child-bearing potential).
Prior radiation:	☑ The patient has not received prior radiation treatment to the same area.
Pacemaker/implanted electronic medical device presents?	☑ No
Other implants (e.g. hip replacement):	☑ Patient has no known implants in the treatment area
Autoplan start:	☑ Automatically

Treatment Specific Questions (Cervix)

Primary disease extent:	☑ Limited to cervix, no vaginal or lymph node involvement.
Patient positioning:	☑ Supine
Treatment technique:	☑ 4 field box
Treatment machine:	☑ LINAC A
Field blocks:	☑ Use MLCs

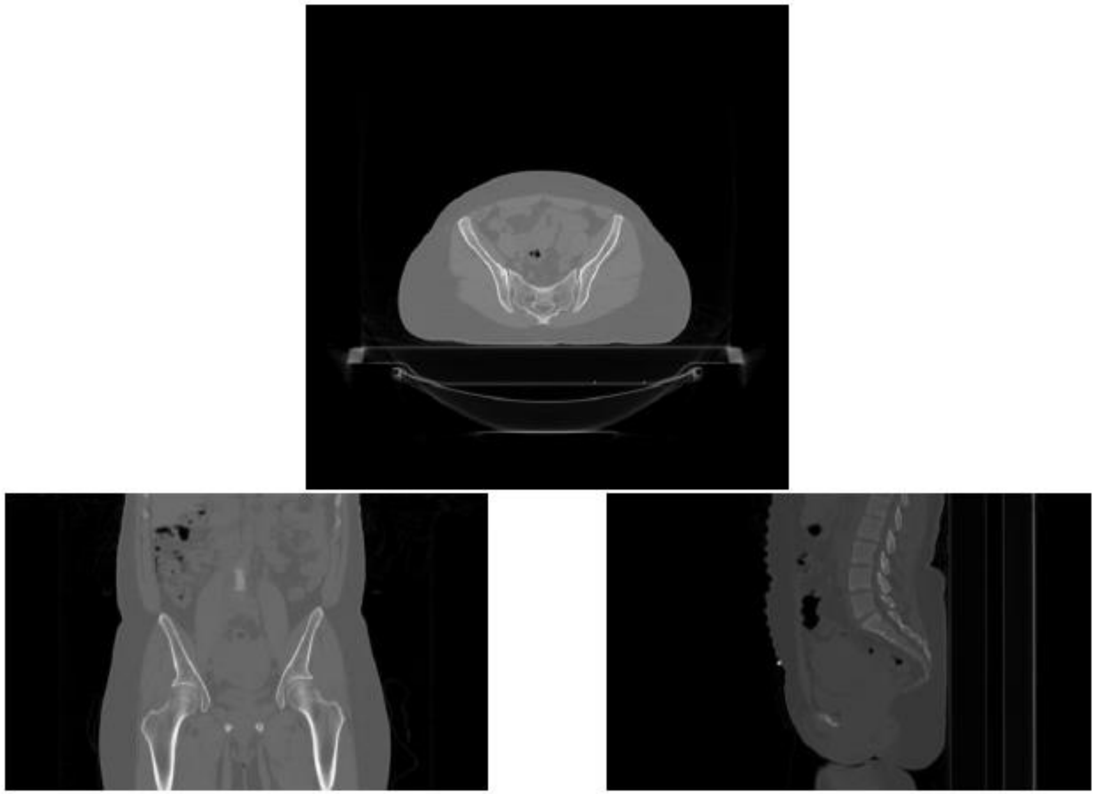
Dose Prescription

Prescribed Total Dose: 4500 cGy (180 cGy/fraction)
Number of Fraction: 25

Plan Order GUID: 692c0117-6b28-4a74-8447-dbaea0d1f2ab

Approved by: Demo Laura Court **Date:** 1/5/2017 4:37:35 PM

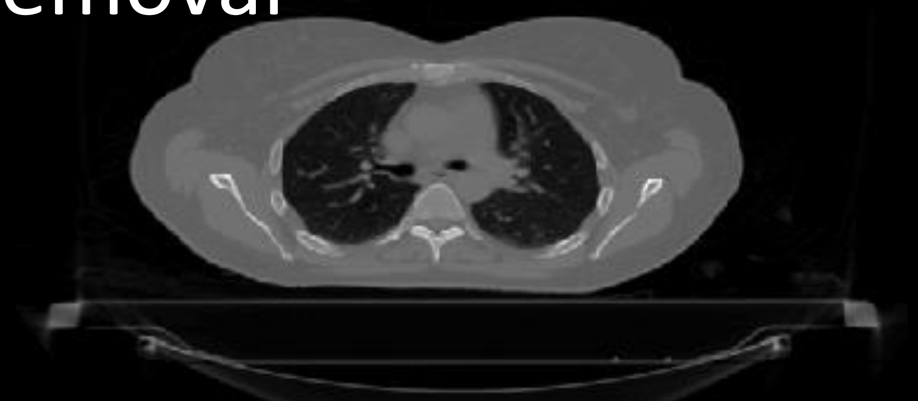
Name:	MDA11^ ^^^
MRN:	MDA11
Modality:	CT
Image Date:	2011-06-10 11:31:57
Number of Slices:	160
Series Number:	2
Series Description:	



CT Approval GUID: feeaebc8-9ea1-402b-8e77-edeafe3bbdab

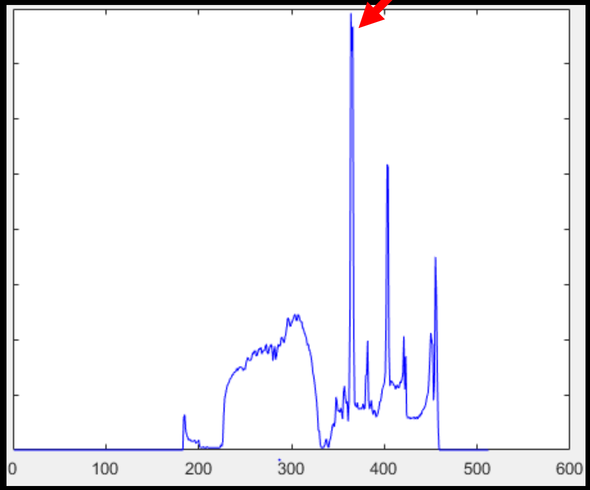
Approved by: Demo Laurence Court **Date:** 2017-03-31 09:35:49

CT Table Removal



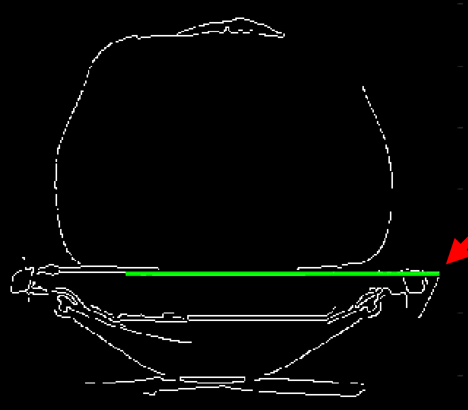
Method 1: ***Peak Detection***
By finding peaks slice by slice at sum projection signal along lateral direction.

Table top as a peak



Method 2: ***Line Detection***
By detecting Hough lines at maximum intensity projection image.

Table top as a line

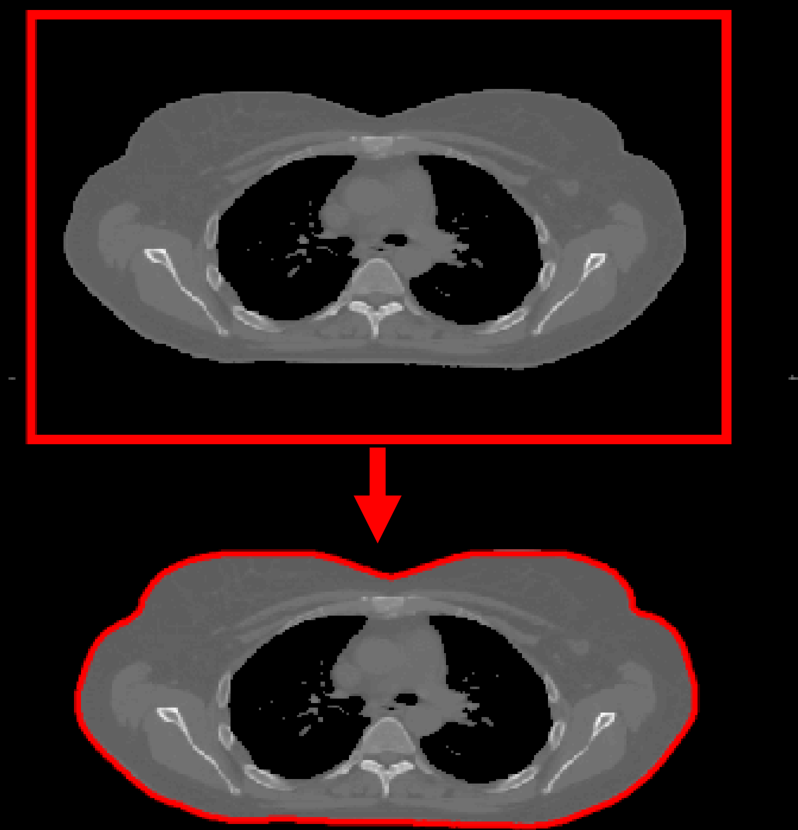


- Average difference between two approaches: 2.6 ± 1.6mm (max: 4.9mm)

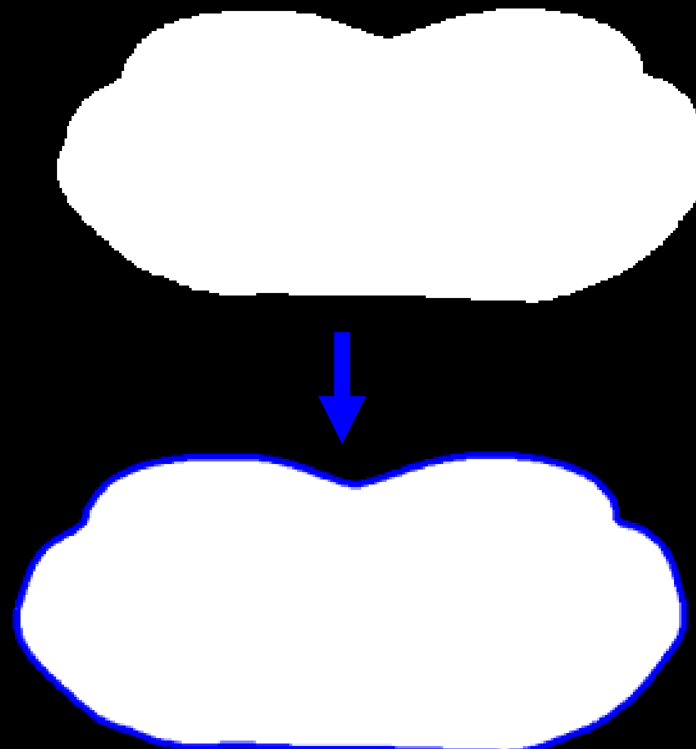
Work by Lifei Zhang

Body Contour

Method 1: ***Active Contour***
By contracting initial active contour to the body edge.



Method 2: ***Intensity Thresholding***
By thresholding CT image into binary mask.



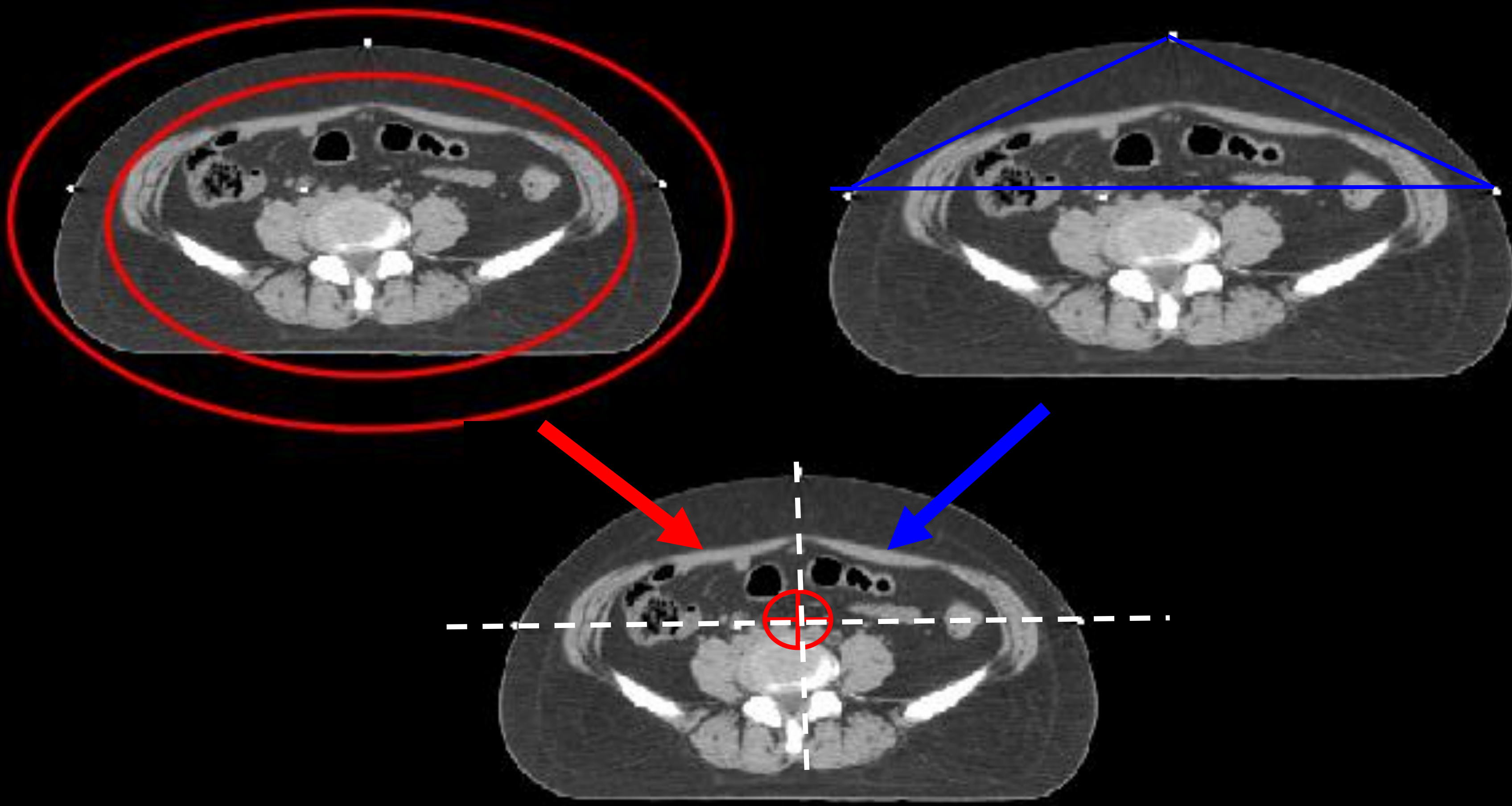
- Average agreement = 0.6mm, Average max: 7.6mm

Work by Lifei Zhang

Marked Isocenter Detection

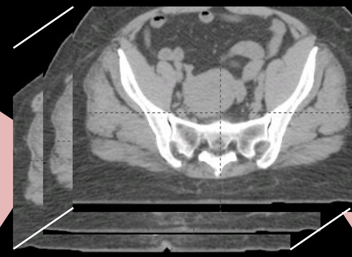
Method 1: ***Body Ring Method***
By searching BB candidates in the body ring domain.

Method 2: ***BB Topology Method***
By searching BBs that constitute the triangle topology.



- Average difference between two approaches: 0.4 ± 0.8mm (max: 3.0mm)

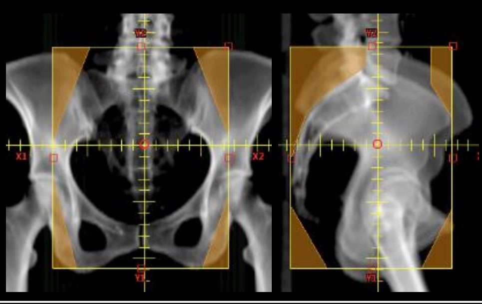
Determine the jaws and blocks



1st Algorithm
"3D Method"

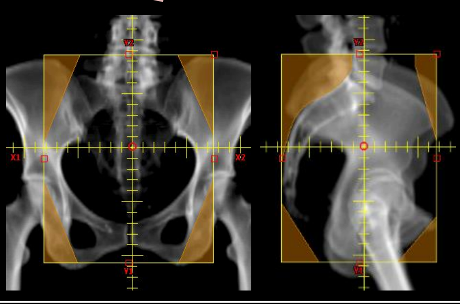
Input: Patient CT
And Isocenter

2nd Algorithm
"2D Method"



Output: treatment fields

Inter-compare

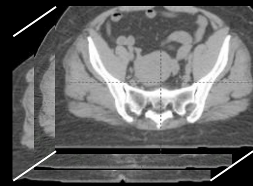


Output: treatment fields

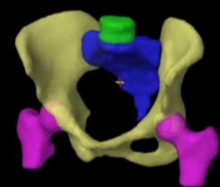
Work by Kelly Kisling

"3D Method" algorithm

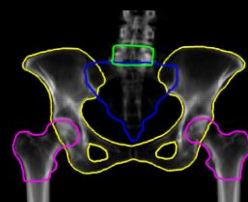
Inputs: Patient CT and Isocenter



Segment bony anatomy using multi-atlas deformable registration



Project these 3D segmentations into the 2D plane of the BEV



On the projections, identify landmarks (e.g. inferior edge of the obturator foramen)

Define the treatment field borders based on these landmarks

Output: 4-field box treatment fields

"2D Method" algorithm

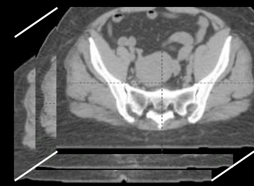
Inputs: Patient CT and Isocenter

Output: 4-field box treatment fields

Work by Kelly Kisling

"3D Method" algorithm

Inputs: Patient CT and Isocenter



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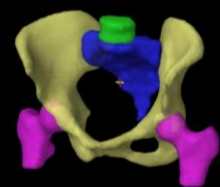

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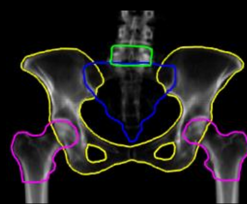

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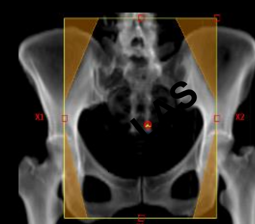
Output: 4-field box treatment fields

"2D Method" algorithm

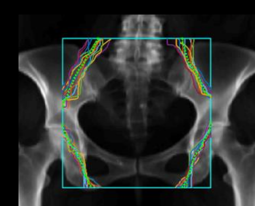
Inputs: Patient CT and Isocenter

Create DRRs at each beam angle from the patient CT

Deform an atlas of DRRs to the patient DRRs. The atlas DRRs have corresponding treatment fields.



Apply deformations to the treatment fields to obtain deformed blocks



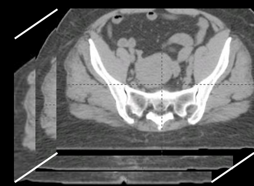
Define the treatment field borders by least-squares fitting to the set of deformed blocks

Output: 4-field box treatment fields

Work by Kelly Kisling

“3D Method” algorithm

Inputs: Patient CT and Isocenter



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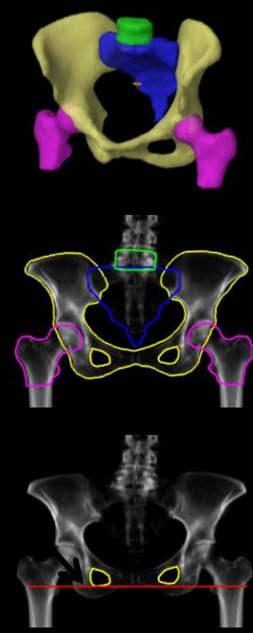

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Apply deformations to the treatment fields to obtain deformed blocks

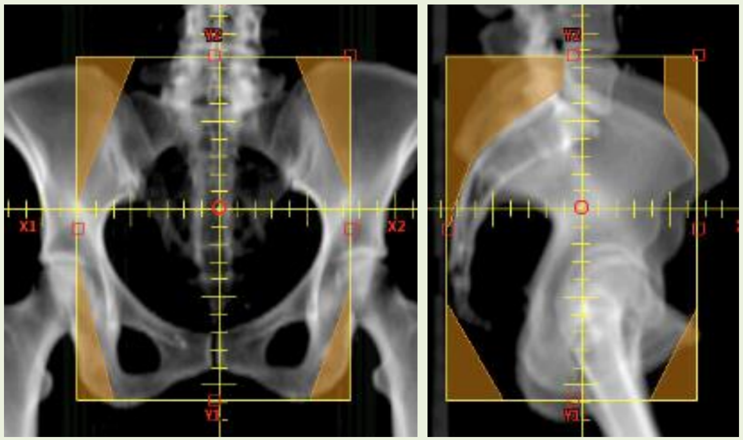
Define the treatment field borders by least-squares fitting to the set of deformed blocks

Output: 4-field box treatment fields

Work by Kelly Kisling

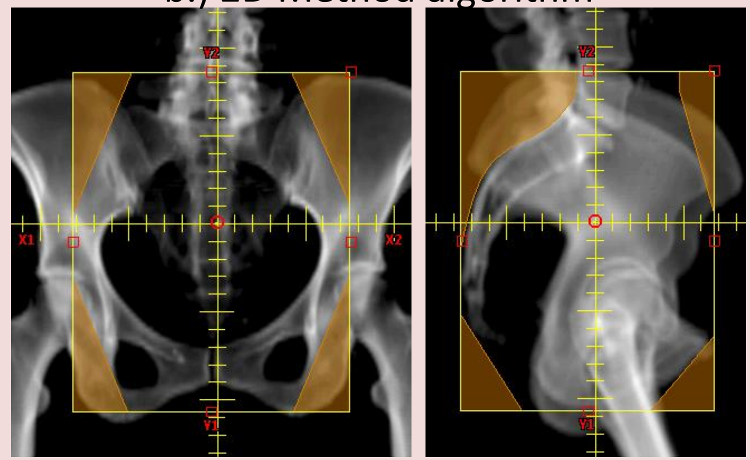
Results of 39 test patient CTs (now tested on ~200)

a.) 3D Method algorithm



Anterior Right lateral

b.) 2D Method algorithm



Anterior Right lateral

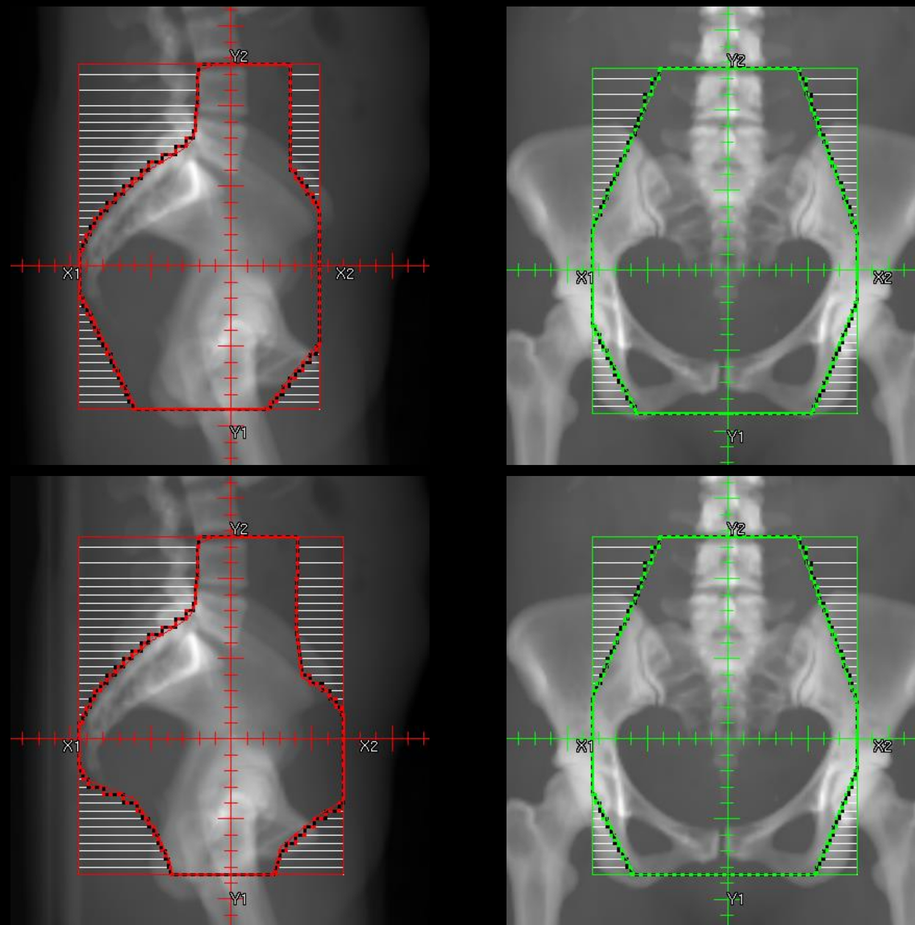
Physician Rating	3D Method	2D Method
Per Protocol	62%	17%
Acceptable Variation	34%	62%
Unacceptable Deviation	4%	21%

Work by Kelly Kisling

MDA clinical version deployed
15 patients so far

Fields from the Auto-planner

Fields with Physician edits

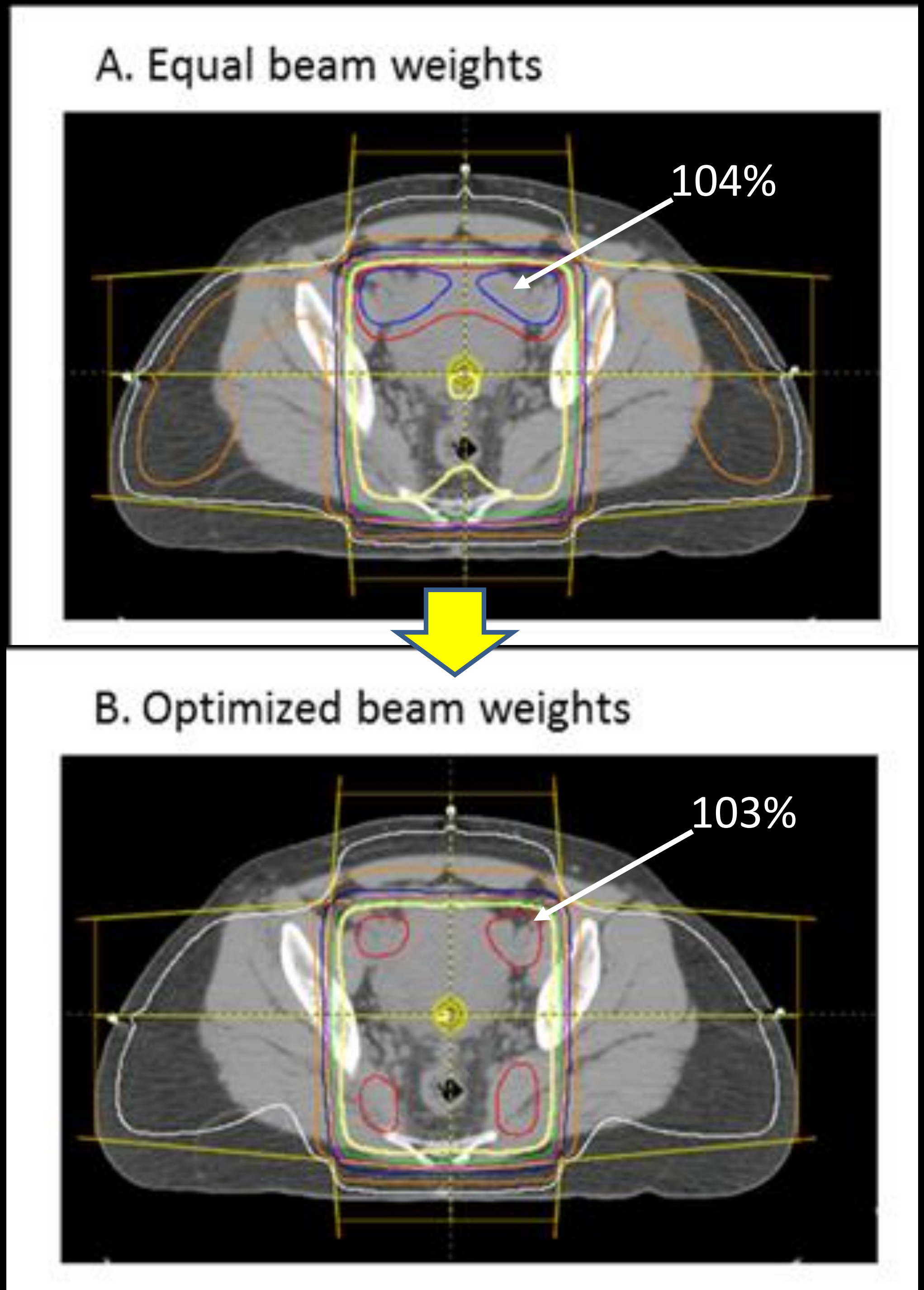


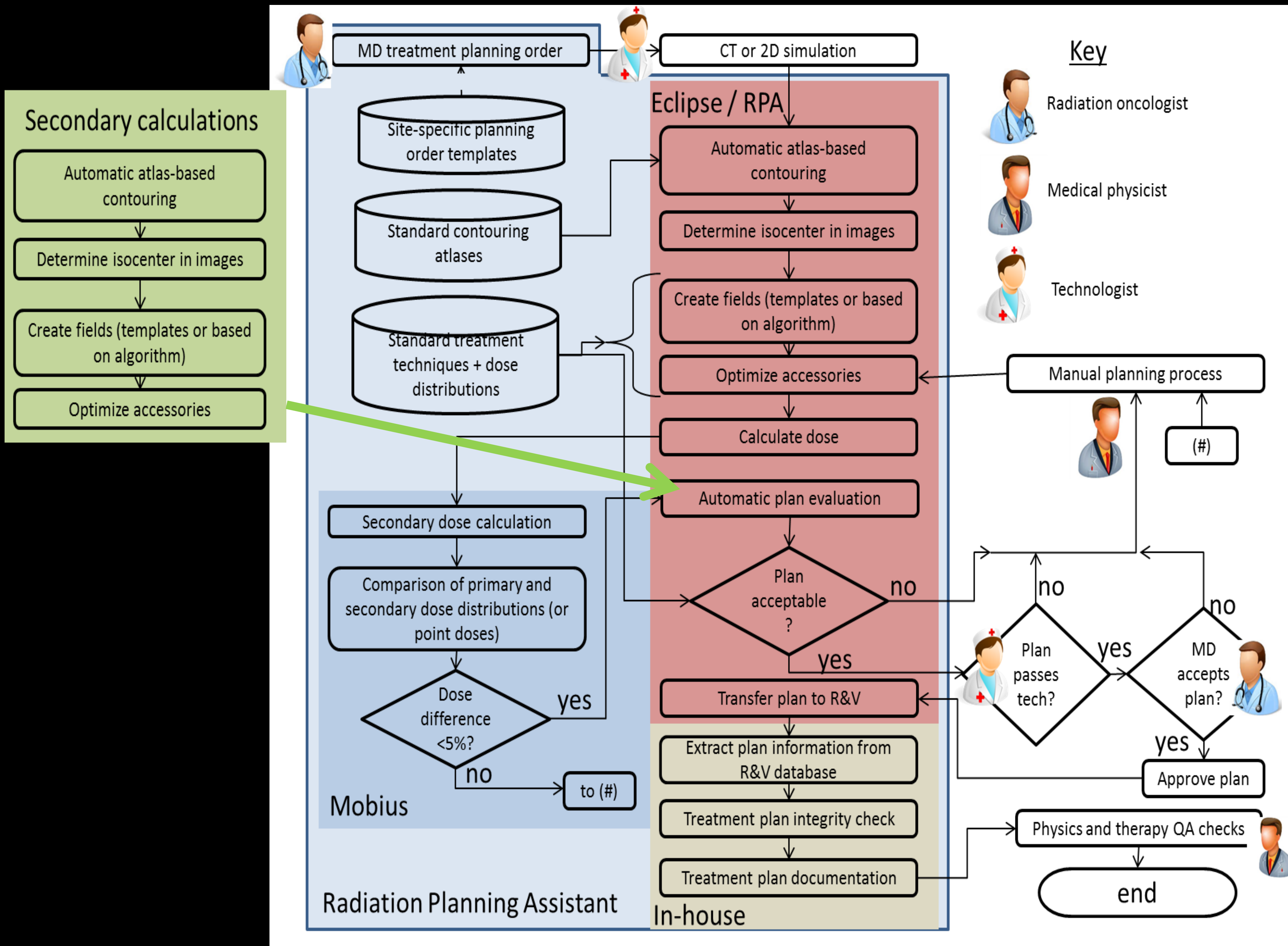
Right Lateral Field **Anterior Field**

Beam weight optimization

- Least-squares optimization to give a uniform dose distribution within the 95% isodose volume
- Tested on 21 patients
- Average hotspot reduction 106.4% to 104.9%
- No loss in coverage

Work by Kelly Kisling




Secondary calculations
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Create fields (templates or based on algorithm)
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Key
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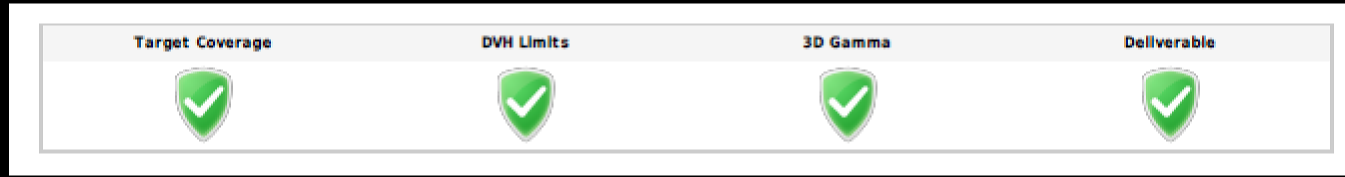
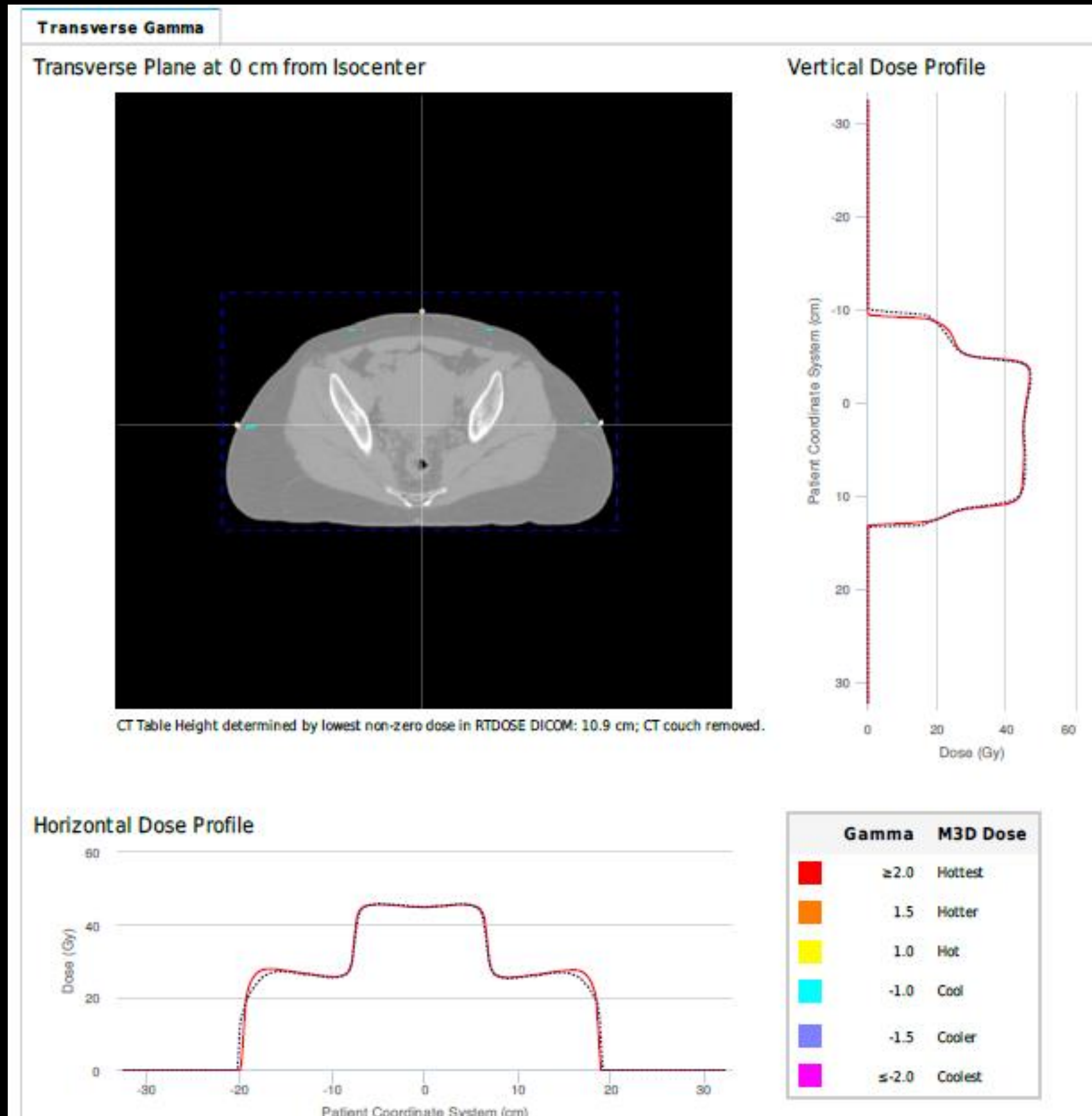
Technologist
Site-specific planning order templates
Standard contouring atlases
Standard treatment techniques + dose distributions
Eclipse / RPA
Automatic atlas-based contouring
Determine isocenter in images
Create fields (templates or based on algorithm)
Optimize accessories
Calculate dose
Automatic plan evaluation
Plan acceptable ?
no
yes
Manual planning process
(#)
Plan passes tech?
no
yes
MD accepts plan?
no
yes
Approve plan
Transfer plan to R&V
Secondary dose calculation
Comparison of primary and secondary dose distributions (or point doses)
Dose difference <5%?
yes
no
to (#)
Mobius
Extract plan information from R&V database
Treatment plan integrity check
Treatment plan documentation
Physics and therapy QA checks
end
Radiation Planning Assistant
In-house

Mobius dose verification

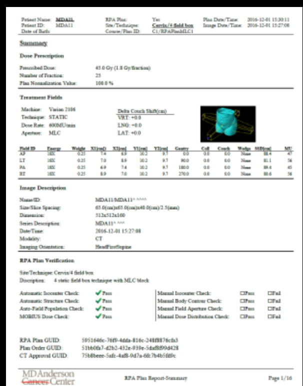
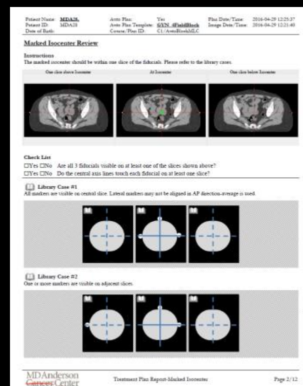
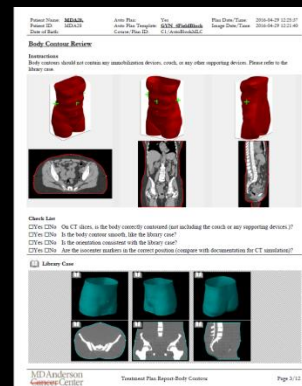
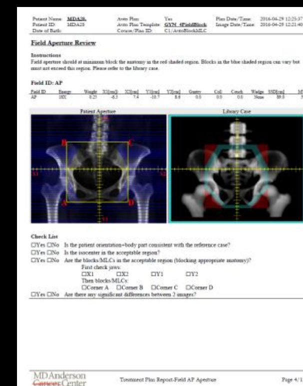
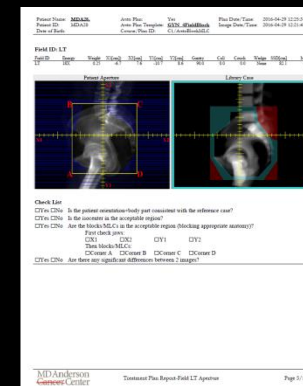
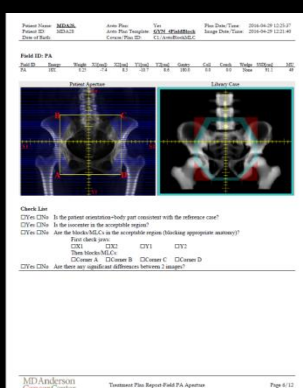
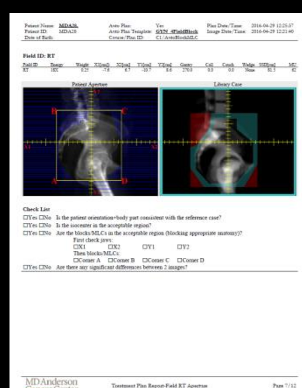
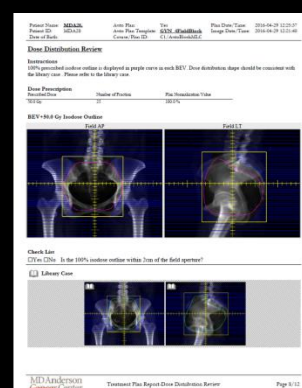
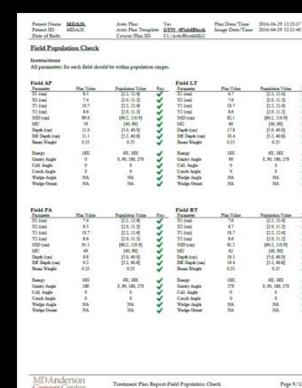




Initial technical review

- Double check of vital plan check functions
- Only get to this point if passes all internal QA checks
- Technical items checked:
  - Marked isocenter
  - Patient orientation, laterality and site
  - Body contour
  - CT processing (couch removal)
  - Field apertures
  - Any significant artifacts or differences
  - Dose calculation complete
- Purpose designed document to lead the user through the checks

Technical review paperwork

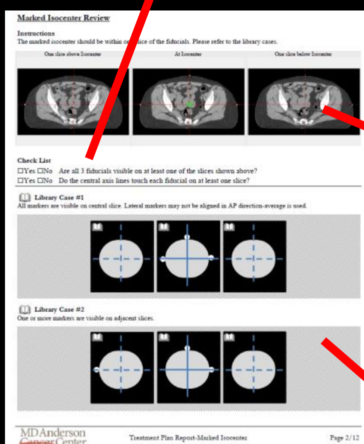










Marked isocenter

Checklist

❑Yes ❑No : Are all 3 fiducials visible on at least one of the slices shown?

❑Yes ❑No : Do the central axis lines touch each fiducial on at least one slice?



Marked Isocenter Review

Instructions

The marked isocenter should be within one slice of the fiducials. Please refer to the library cases.

One slice above Isocenter	At Isocenter	One slice below Isocenter

Check List

☐Yes ☐No Are all 3 fiducials visible on at least one of the slices shown above?

☐Yes ☐No Do the central axis lines touch each fiducial on at least one slice?

Library Case #1

All markers are visible on central slice. Lateral markers may not be aligned in AP direction-average is used.

Library Case #2

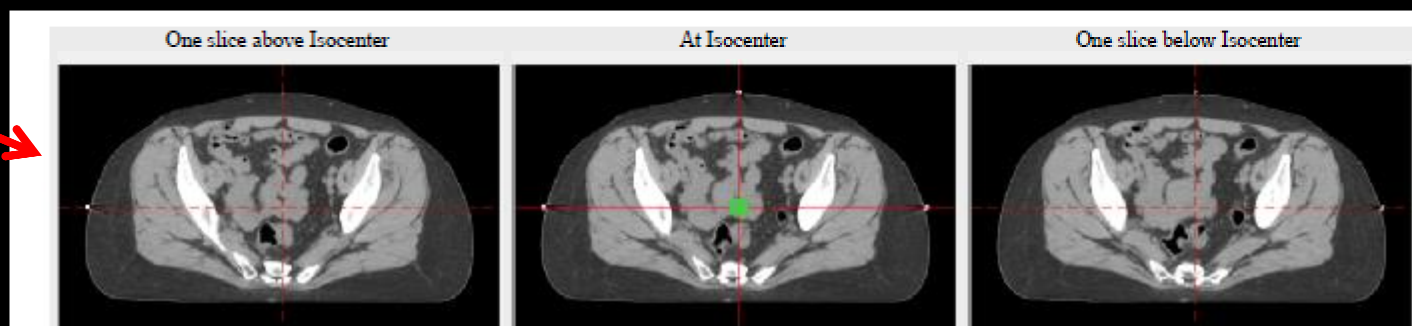
One or more markers are visible on adjacent slices.

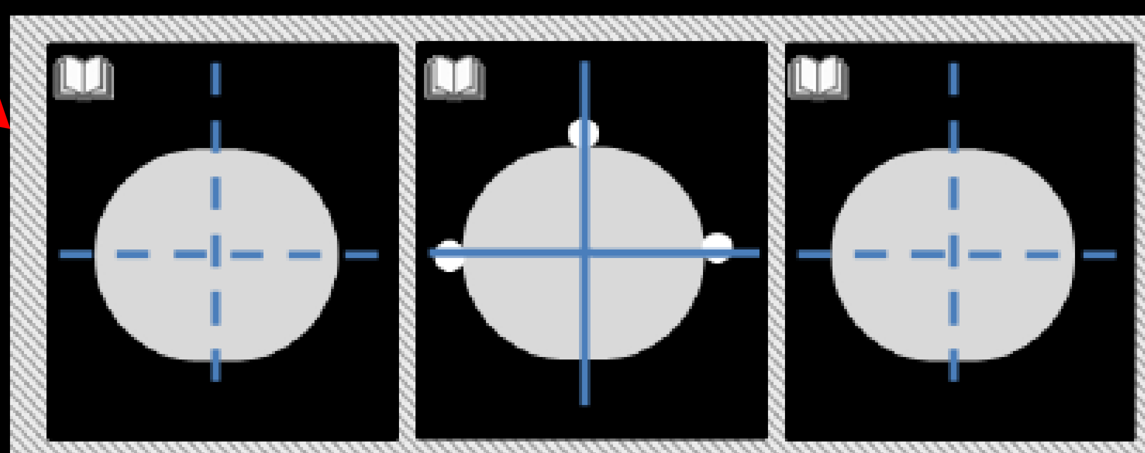
MD Anderson Cancer Center

Treatment Plan Report-Marked Isocenter

Page 2/12

Patient results

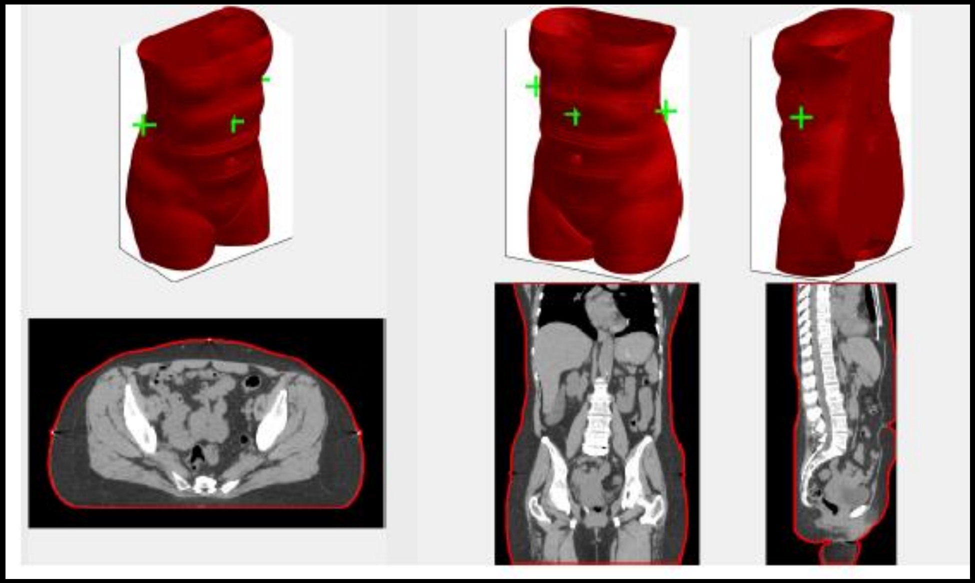




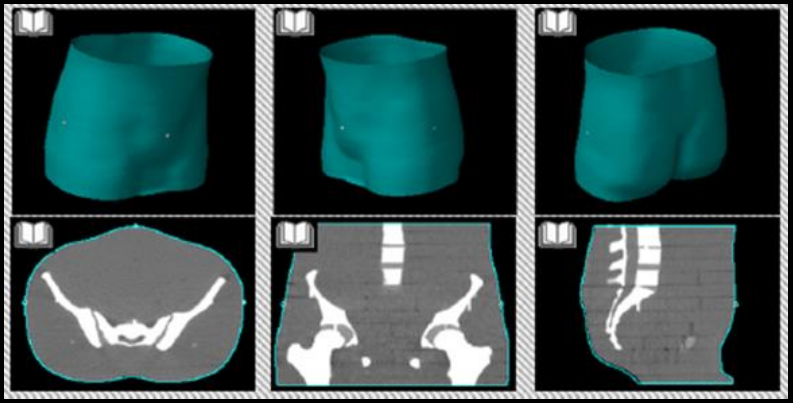
Library examples

Body contour

Patient results



Library examples



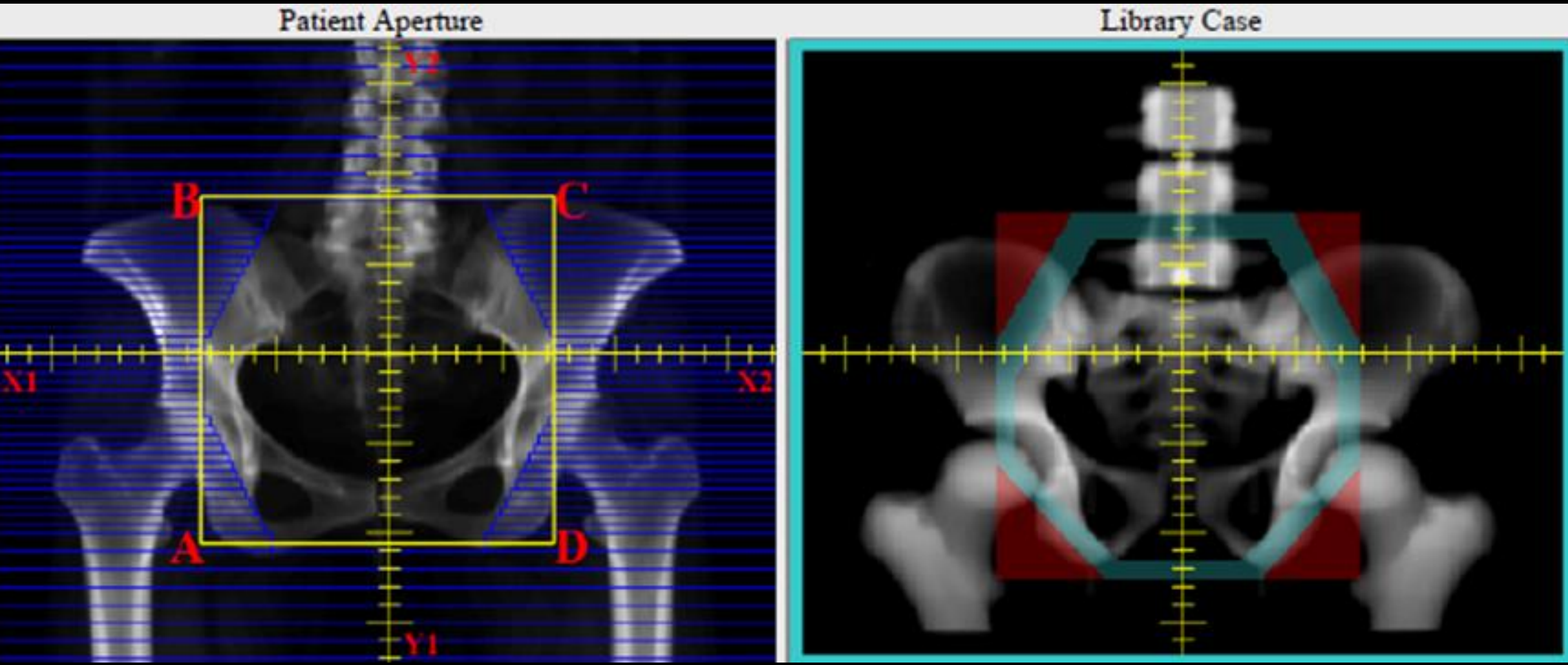
Checklist

❑Yes ❑No : On the CT slices, is the body correctly contoured (e.g. not including the couch)?

❑Yes ❑No : Is the body contour smooth, like the library case?

❑Yes ❑No : Is the orientation consistent with the library case?

Field apertures



Checklist

❑Yes ❑No : Is the patient orientation and body part consistent with the reference case

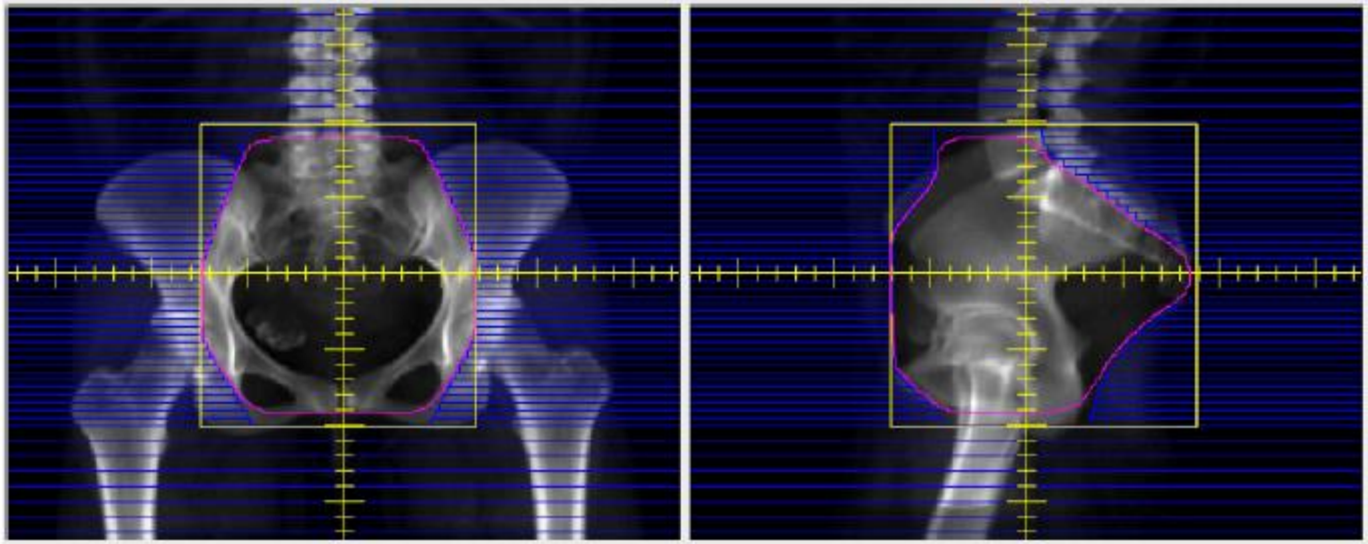
❑Yes ❑No : Are the blocks/MLCs in the acceptable region?

❑Yes ❑No : Are there any significant differences between the patient and library images?

Completeness of dose calculation

BEV+45.0*95% Gy Isodose Outline

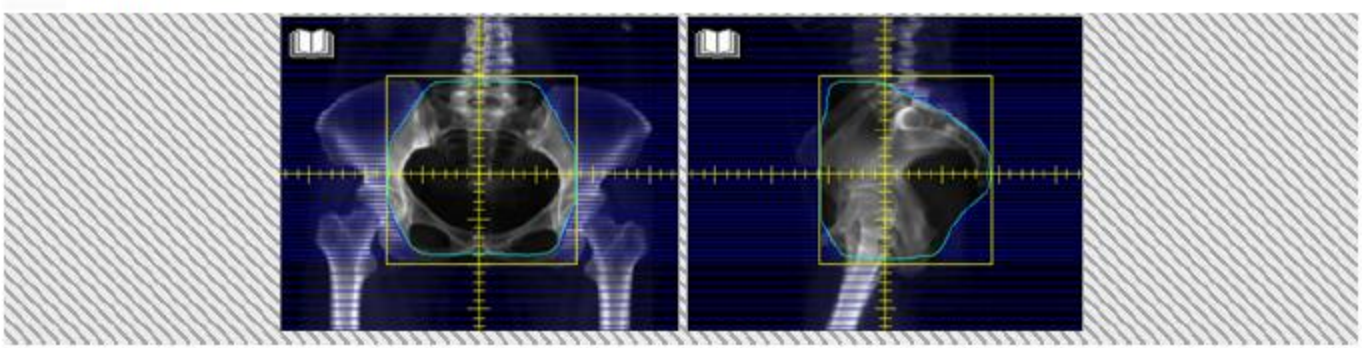
Field AP | Field LT



Check List

☐Yes ☐No Is the 95% isodose outline within 2cm of the field aperture?

Library Case



Patient Name:	**MDA11,**	RPA Plan:	Yes	Plan Date/Time:	2016-12-01 15:30:11
Patient ID:	MDA11	Site/Technique:	**Cervix/4 field box**	Image Date/Time:	2016-12-01 15:27:08
Date of Birth:		Course/Plan ID:	C1/RPAPlanMLC1		

Auto Table Removal Check

Instructions

Two independent methods were used to detect table position.The difference between them are compared to decide the result of primary method is passed or failed.

Result

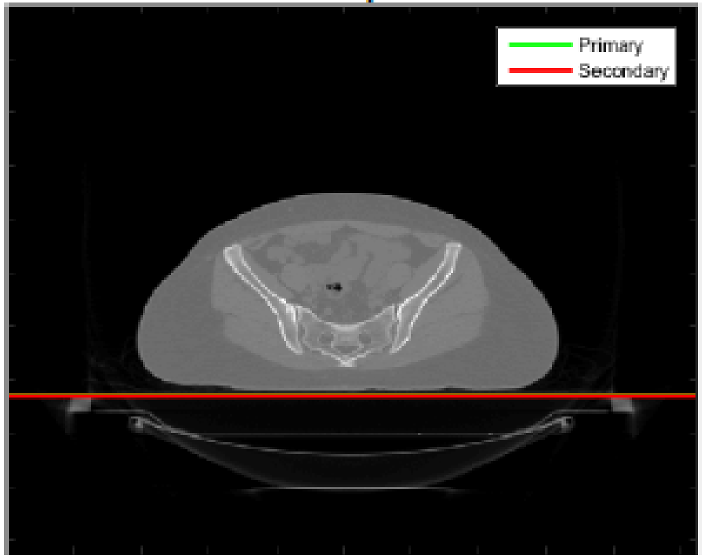
Primary Method	Secondary Method	Pass
By SliceAccumPeak	By SliceHough	✓

Metrics

Metric	Value	Criteria	Pass
Distance Difference	0.13cm	Pass: <= 0.5cm. Fail: > 0.5cm.	✓

Images

Comparison of table poisions between primary and secondary methods



Lifei Zhang

Auto Body Contour Check

Instructions

Two independent methods were used to detect body contour. The difference between them are compared to decide the result of primary method is passed or failed.

Result

Primary Method	Secondary Method	Pass
By Threshold	By ActiveContour	✓

Metrics

Metric	Value	Criteria	Pass
Max Distance Difference	0.28cm	Pass: <= 0.5cm. Fail: > 0.5cm.	✓
Average Distance Difference	0.046cm	Pass: <= 0.5cm. Fail: > 0.5cm.	✓
Dice Index	1	Pass: >= 0.97. Fail: < 0.97.	✓

Images

Primary Body Contour

Secondary Body Contour

Patient Name:	MDA11,	RPA Plan:	Yes	Plan Date/Time:	2016-12-01 15:30:11
Patient ID:	MDA11	Site/Technique:	Cervix/4 field box	Image Date/Time:	2016-12-01 15:27:08
Date of Birth:		Course/Plan ID:	C1/RPAPlanMLC1		

Auto Isocenter Check

Instructions

Two independent methods were used to detect marked isocenter.The distance between 2 isocenter are computed to decide the result of primary method is passed or failed.

Result

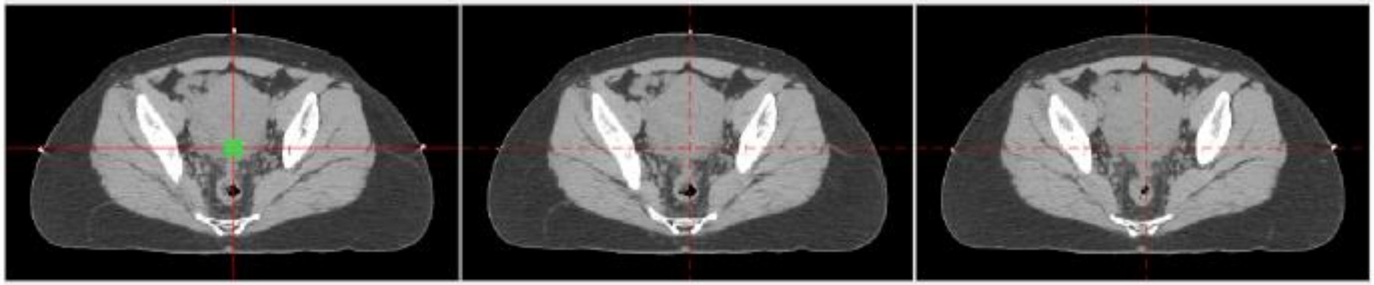
Primary Method	Secondary Method	Pass
By Body Ring	By Topology	✔

Metrics

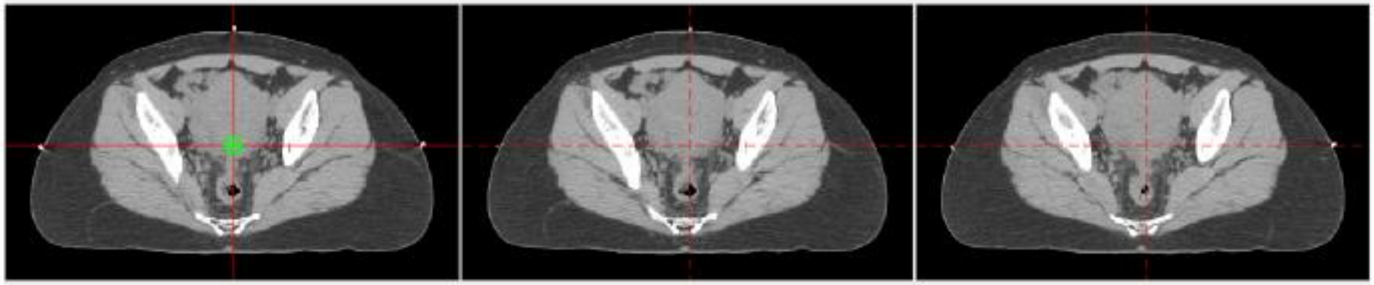
Metric	Value	Criteria	Pass
Distance	0.0065cm	Pass: <= 0.5cm. Fail: > 0.5cm.	✔

Images

Primary Isocenter



Secondary Isocenter



Auto Block Check

Instructions

Primary block geometry is checked against a set of QA blocks. The confidence level is computed.

Result

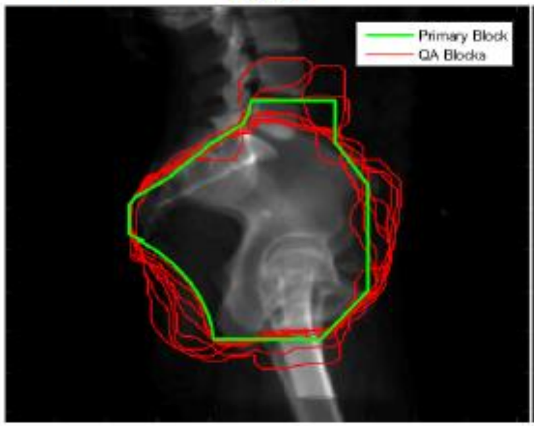
Primary Method	Secondary Method	Pass
By 3D ROI Projection	By Multiple QA Blocks	✔

Metrics

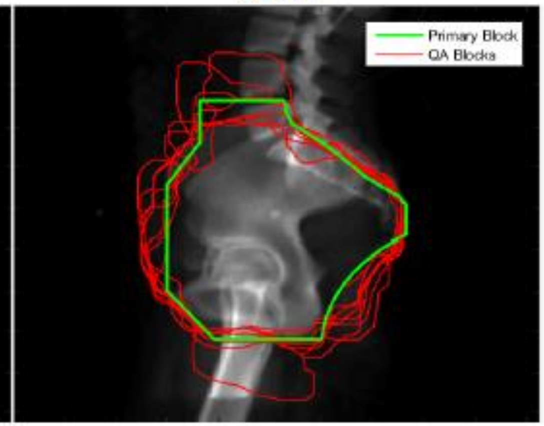
Metric	Value	Criteria	Pass
Confidence Level	0.95	Pass: >= 0.9. Fail: < 0.9.	✔

Images

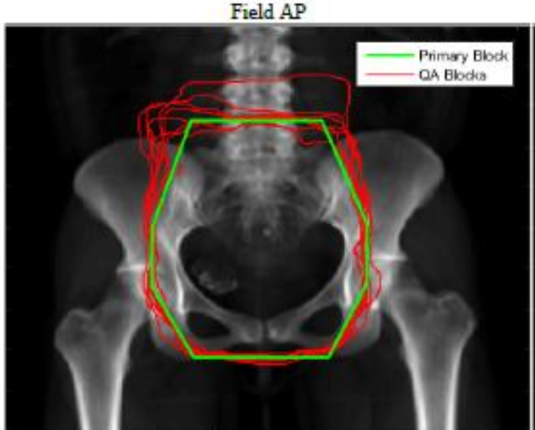
Field RT



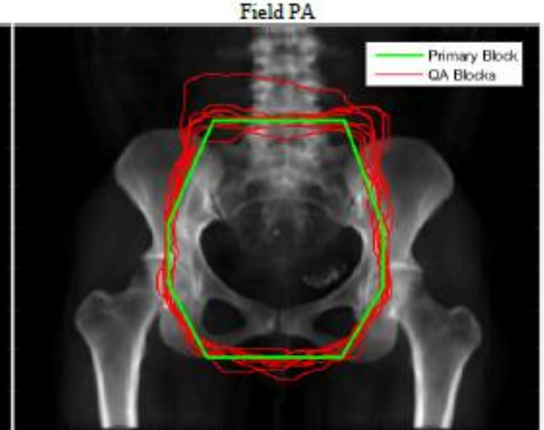
Field LT



Field AP



Field PA



Plan QA: Comparison with population ranges

- Some ranges are quite tight, so provide reasonable (backup) QA
  - E.g. Total range of MU is 10%
- Some ranges are much looser
  - Range of jaw positions is ~2.5cm in lateral and AP directions, 6cm in SI direction

Jaw positions – population statistics

	gantry: 0deg	
	x	y
average	16.8	21.3
St. dev.	0.9	1.9
min	15.7	18.5
max	18.2	23.1

Total MU – population statistics

average	208
St. dev.	9
min	200
max	220

Field Population Check

Instructions

All parameters for each field should be within population ranges.

Field AP

Parameter	Plan Value	Population Value	Pass
X1 (cm)	7.4	[2.2, 12.4]	✓
X2 (cm)	6.9	[2.0, 11.2]	✓
Y1 (cm)	10.2	[2.2, 12.4]	✓
Y2 (cm)	9.7	[2.0, 11.2]	✓
SSD (cm)	88.4	[60.2, 110.9]	✓
MU	47	[40, 80]	✓
Depth (cm)	11.6	[5.0, 40.0]	✓
Eff. Depth (cm)	11.7	[5.2, 40.8]	✓
Beam Weight	0.25	0.25	✓
Energy	18X	6X, 18X	✓
Gantry Angle	0	0, 90, 180, 270	✓
Coll. Angle	0	0	✓
Couch Angle	0	0	✓
Wedge Angle	NA	NA	✓
Wedge Orient.	NA	NA	✓

Field LT

Parameter	Plan Value	Population Value	Pass
X1 (cm)	7.0	[2.2, 12.4]	✓
X2 (cm)	8.9	[2.0, 11.2]	✓
Y1 (cm)	10.2	[2.2, 12.4]	✓
Y2 (cm)	9.7	[2.0, 11.2]	✓
SSD (cm)	81.1	[60.2, 110.9]	✓
MU	56	[40, 80]	✓
Depth (cm)	18.9	[5.0, 40.0]	✓
Eff. Depth (cm)	19.5	[5.2, 40.8]	✓
Beam Weight	0.25	0.25	✓
Energy	18X	6X, 18X	✓
Gantry Angle	90	0, 90, 180, 270	✓
Coll. Angle	0	0	✓
Couch Angle	0	0	✓
Wedge Angle	NA	NA	✓
Wedge Orient.	NA	NA	✓

Field PA

Parameter	Plan Value	Population Value	Pass
X1 (cm)	6.9	[2.2, 12.4]	✓
X2 (cm)	7.4	[2.0, 11.2]	✓
Y1 (cm)	10.2	[2.2, 12.4]	✓
Y2 (cm)	9.7	[2.0, 11.2]	✓
SSD (cm)	89.4	[60.2, 110.9]	✓
MU	45	[40, 80]	✓
Depth (cm)	10.6	[5.0, 40.0]	✓
Eff. Depth (cm)	10.0	[5.2, 40.8]	✓
Beam Weight	0.25	0.25	✓
Energy	18X	6X, 18X	✓
Gantry Angle	180	0, 90, 180, 270	✓
Coll. Angle	0	0	✓
Couch Angle	0	0	✓
Wedge Angle	NA	NA	✓
Wedge Orient.	NA	NA	✓

Field RT

Parameter	Plan Value	Population Value	Pass
X1 (cm)	8.9	[2.2, 12.4]	✓
X2 (cm)	7.0	[2.0, 11.2]	✓
Y1 (cm)	10.2	[2.2, 12.4]	✓
Y2 (cm)	9.7	[2.0, 11.2]	✓
SSD (cm)	80.6	[60.2, 110.9]	✓
MU	56	[40, 80]	✓
Depth (cm)	19.4	[5.0, 40.0]	✓
Eff. Depth (cm)	19.7	[5.2, 40.8]	✓
Beam Weight	0.25	0.25	✓
Energy	18X	6X, 18X	✓
Gantry Angle	270	0, 90, 180, 270	✓
Coll. Angle	0	0	✓
Couch Angle	0	0	✓
Wedge Angle	NA	NA	✓
Wedge Orient.	NA	NA	✓

Status of cervical cancer autoplanning

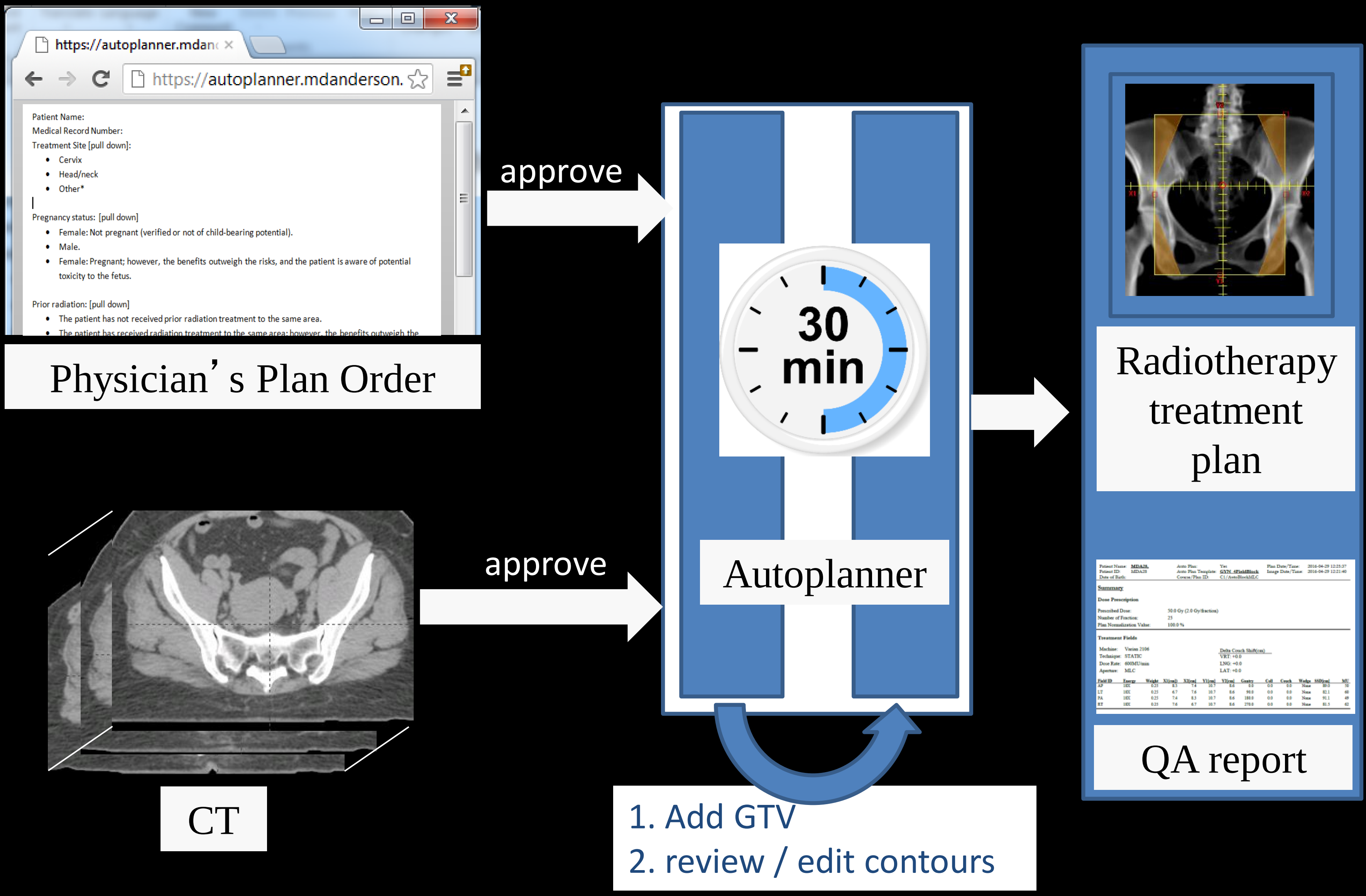
- 3D algorithm deployed to MDACC clinical use
- Workflow designed and integrated
- Secondary (verification) algorithms developed
- Starting testing on 600+ patients
  - ~95% pass rate (first 200 patients)
  - QA criteria
- Then testing using local data at Stellenbosch, Santo Tomas, and others

NEW: We now have a 2D algorithm for use with digital simulator images – looking for collaborators to help check these…. (we don't have many images…..)

Head and neck treatments

- Range of complexities in treatments
  - VMAT or IMRT
  - Opposed laterals / off-cord cone-downs
  - Complex conformal plans
- Starting with VMAT (IMRT)
  - Auto-contouring normal tissue
  - Auto-contouring low-risk CTV
  - Manual contouring of GTV
  - RapidPlan (Eclipse)

Workflow overview (user's perspective)



Treatment Specific Questions (HN)

Head/Neck primary site:	☑ Oropharynx
Positive lymph node involvement:	☑ Right cervical neck
Elective left cervical neck coverage required:	☑ Levels II-IV ☑CTV3
Elective right cervical neck coverage required:	☑ Levels IB-V ☑CTV2
Elective left retropharyngeal lymph node coverage required :	☑ Yes ☑CTV3
Elective right retropharyngeal lymh node coverage required :	☑ Yes ☑CTV2
Treatment machine:	☑ LINAC A
Treatment technique:	☑ VMAT

Dose Prescription

Number of Fraction: 33

Prescribed Total Dose:
GTV: 7000 cGy (212 cGy/fraction)
CTV1: 7000 cGy (212 cGy/fraction)
CTV2: 6300 cGy (191 cGy/fraction)
CTV3: 5700 cGy (173 cGy/fraction)

Normal Tissue Dose Constraints

☑The DVH objectives and constraints listed below are appropriate for this plan.

Spinal Cord: Dmax < 45Gy; Brainstem: Dmax < 54Gy; Rt Parotid: Dmean < 26Gy
Lt Parotid: Dmean < 26Gy; Rt Eye: Dmax < 54Gy; Lt Eye: Dmax < 54Gy

Normal tissue auto-contouring

Multi-atlas segmentation – deformable registration (accelerated "Demon") followed by STAPLE algorithm to fuse contours

- Brain
- Brainstem
- Cochlea
- Esophagus
- Eye
- Lung
- Mandible
- Parotid
- SpinalCord

Data from Rachel McCarroll. Algorithm by Jinzhong Yang and team

Normal tissue auto-contouring

Multi-atlas segmentation – deformable registration (accelerated “Demon”) followed by STAPLE algorithm to fuse contours

Structure	Number	Average	Stdev
Brain	128	4.1	0.5
Brainstem	128	4.2	0.4
Cochleas	256	4.0	0.8
Esophagus	116	3.4	1.0
Eyes	236	4.2	0.6
Lung	113	3.9	0.5
Mandible	128	4.3	0.5
Parotids	254	4.4	0.7
SpinalCord	128	5.0	0.2

- Tested on 128 patients
- Scored by Radiation oncologist.
- 4+ is acceptable without edit
- Fails for non-standard head positions
- Otherwise all pass, except esophagus (and lung)
- Now deployed this to clinical practice

Data from Rachel McCarroll. Algorithm by Jinzhong Yang and team

Deployed to clinical use at MDA

- 150+ patients since May 2016

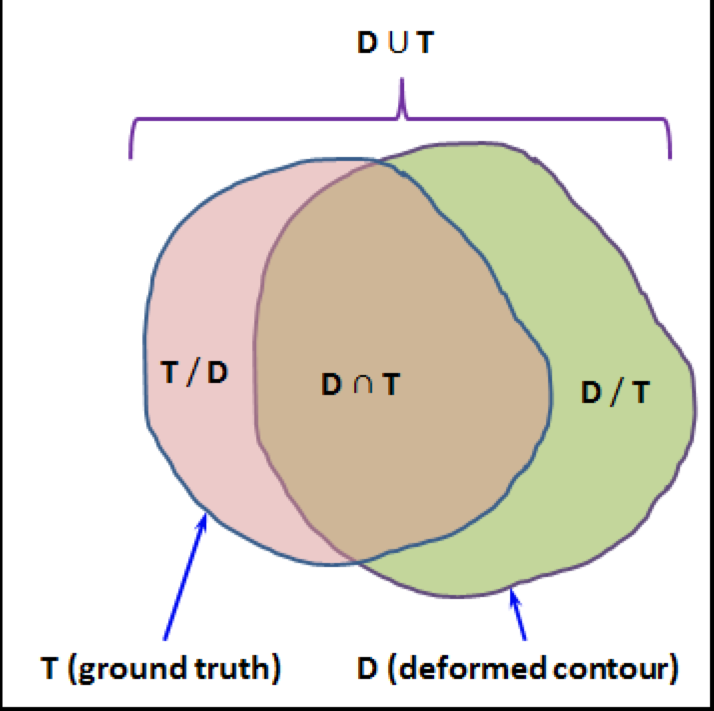
Compare auto-contour pre- and post-edits

	n	DSC	MDA (cm)
Brain	10	0.98	0.07
Brainstem	10	0.88	0.14
Cochlea	18	0.65	0.09
Esophagus	10	0.62	0.30
Eye	20	0.87	0.11
Lung	10	0.92	0.25
Mandible	10	0.90	0.08
Parotid	19	0.84	0.18
SpinalCord	10	0.81	0.14

DSC: Dice similarity coefficient

$$DSC = 2\frac{D \cap T}{|D| + |T|}$$

>0.7 is considered acceptable



Data from Rachel McCarroll

Addition of Varian Deeds algorithm
(a new algorithm, not in Eclipse)
Comparison with physician contours (in clinical plan)

- First scored Varian atlas applied to our patients
- (note difference in patient setup)

	Ratings			
	Deeds		MACs	
	Average	StDev	Average	Stdev
Mandible	3.32	0.88	4.26	0.71
Optic Nerves	3.03	0.75	Not Atlas Structures	
Optic Chiasm	2.26	0.62	Not an Atlas Structure	
Brainstem	3.74	0.62	4.71	0.46
Parotid	2.71	0.76	4.43	0.74
Submandibular Gland	2.81	0.67	Not Atlas Structures	

Addition of Varian Deeds algorithm (Tomas Morgas) Comparison with physician contours (in clinical plan)

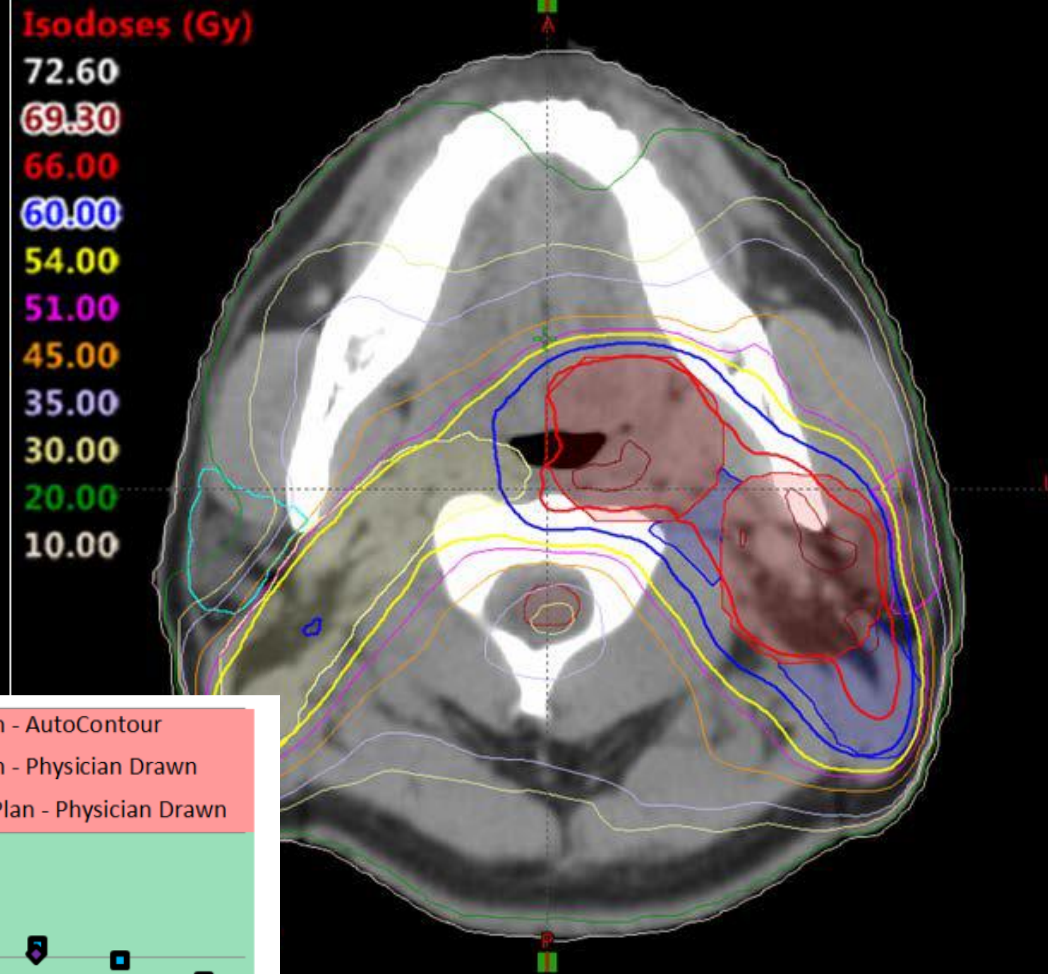
- Second, used our atlas with Varian Deeds, applied to our patients

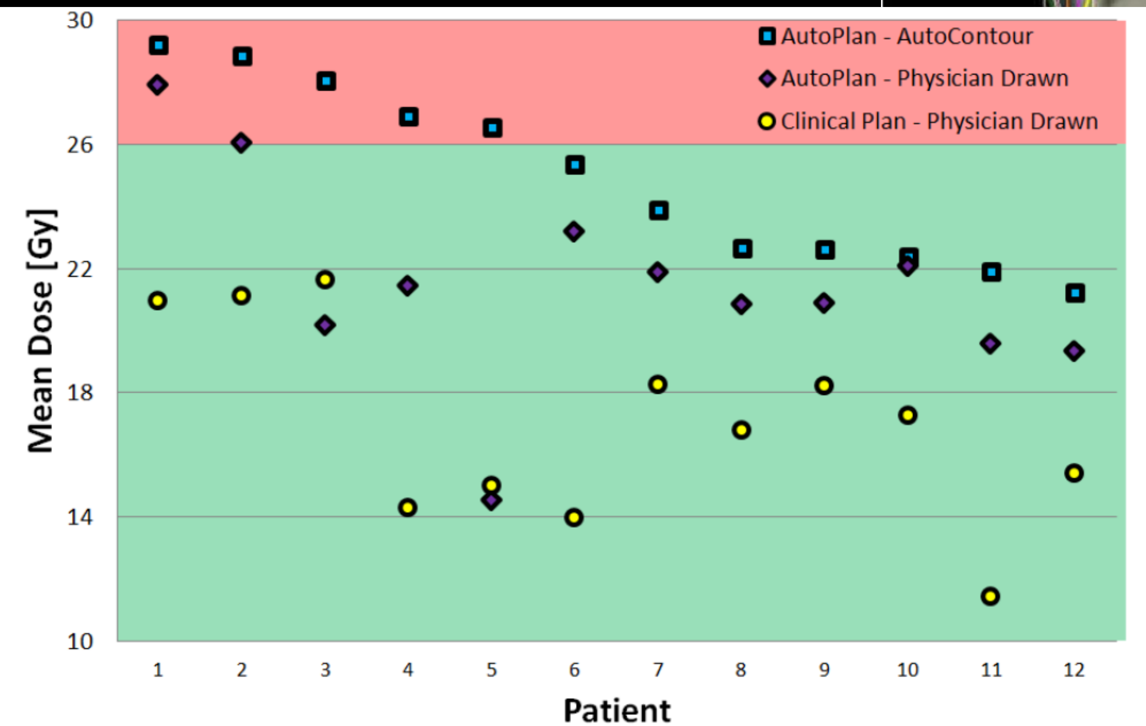
		Dice		MSD (mm)	
Structure	N	In House MACS	Varian Deeds with MDACC Atlas	In House MACS	Varian Deeds with MDACC Atlas
Brain	26	0.98	0.97	1.06	1.36
Brainstem	75	0.80	0.81	2.38	2.24
Cochlea	104	0.50	0.59	1.61	1.46
Esophagus	34	0.64	0.51	3.13	5.90
Eye	68	0.84	0.79	1.42	1.75
Lungs	12	0.76	0.88	8.98	4.33
Mandible	39	0.85	0.80	1.71	2.36
Parotid	140	0.79	0.72	2.37	3.03
SpinalCord	74	0.73	0.71	3.76	5.83

- Next step is to evaluate the use of Deeds for secondary verification of contours

VMAT planning

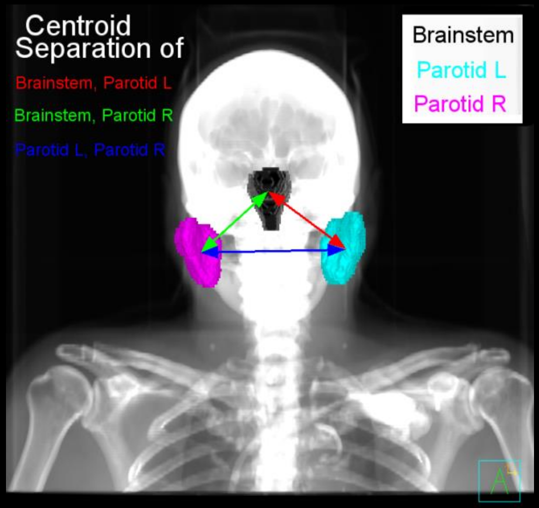
- Average time: 48min (n=30)
- Physician pass rate: >90% (14/15)
  - Contour review
  - Dose distribution review
  - DVH review

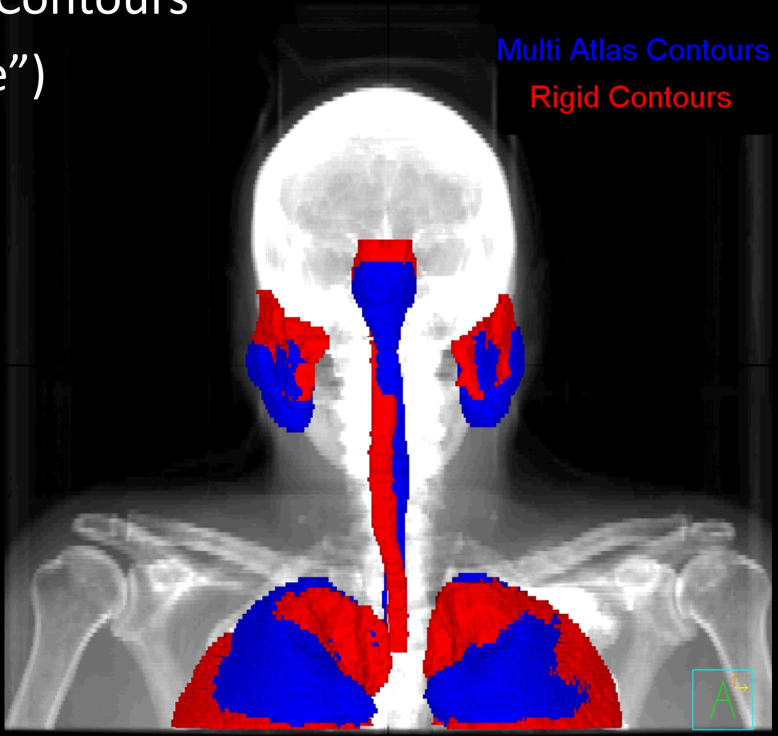




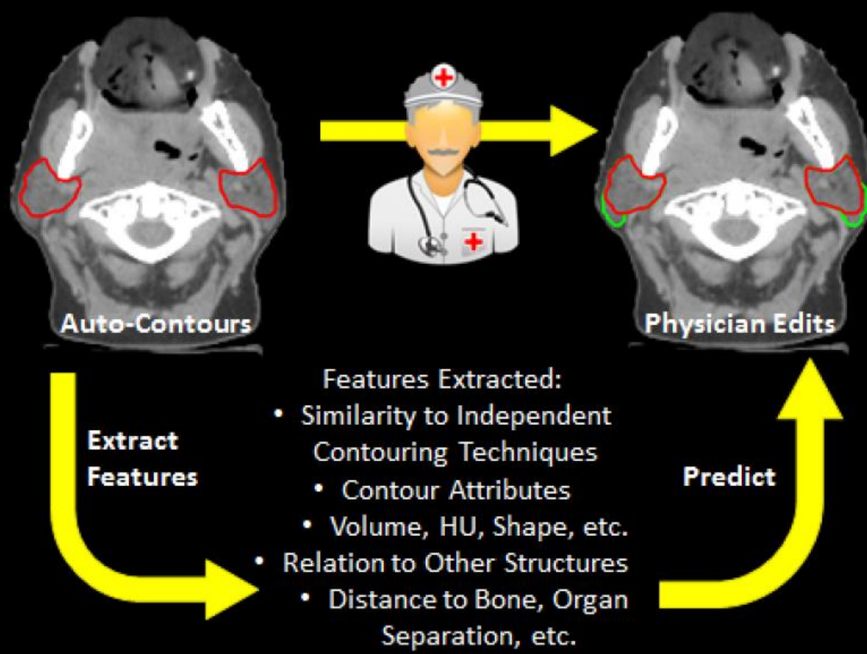
Structure specific population models for automated QA – works-in-progress

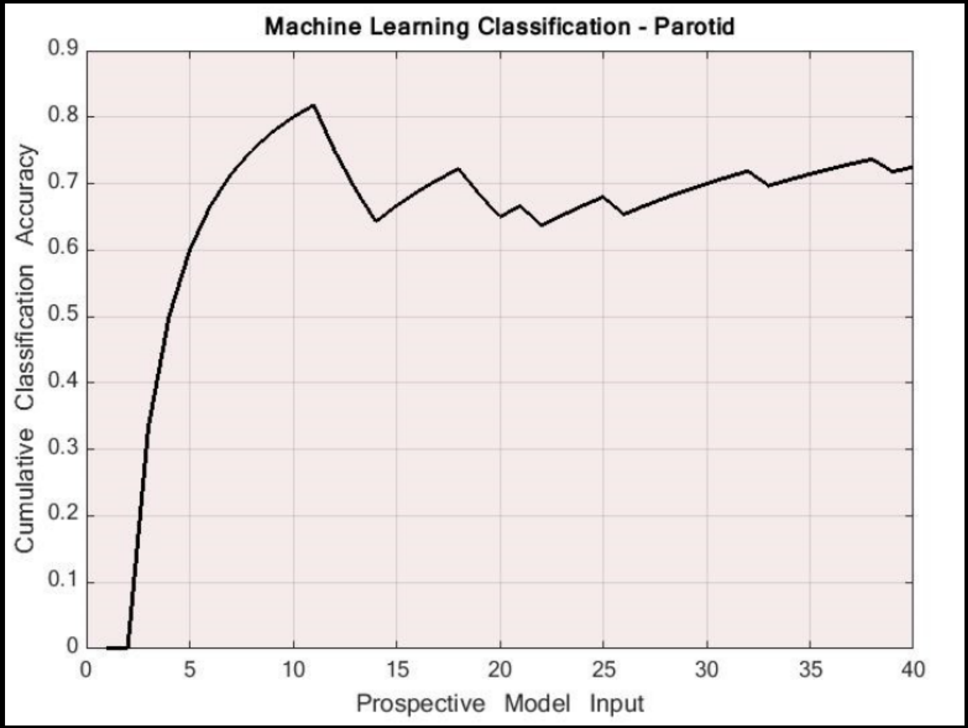
- Example metrics
  - Volume, HU
  - Separation
  - Agreement with Rigidly Registered Contours
  - Slice to Slice Characteristics ("shape")
- Bagged classification tree model





Predicting the need for edits.....





Summary for head and neck cancer treatments

- VMAT/IMRT
  - Normal tissue segmentation
    - complete, tested, and deployed
  - CTV2,CTV3 segmentation
    - Complete and tested
  - Automated planning using RapidPlan
    - mostly complete, but additional assessment needed
  - Automated QA – needs more work

- Opposed laterals
  - Longer timeframe (use similar tools as 4fld cervix)

RPA Deployment process

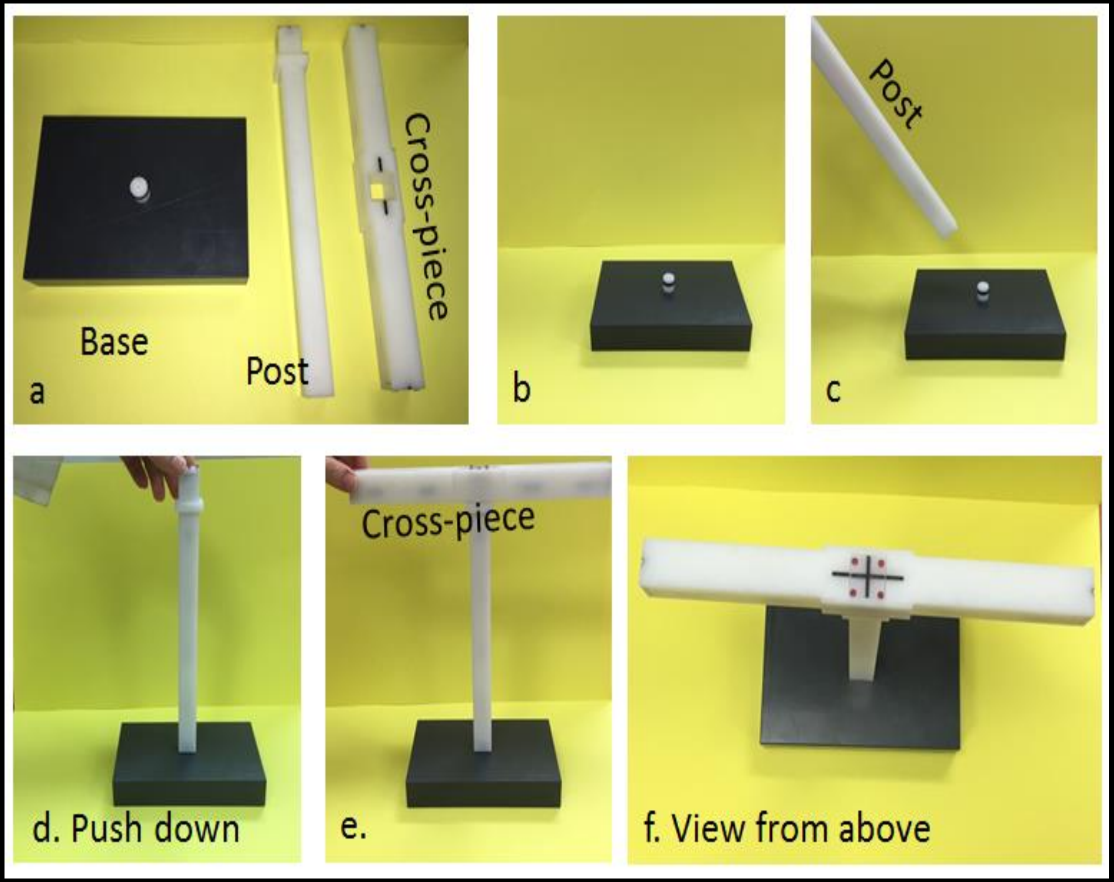
- Demographics questionnaire
- Facility questionnaire
- OSLD output check
  - all photon beams, low-energy electron beams
- Virtual visit

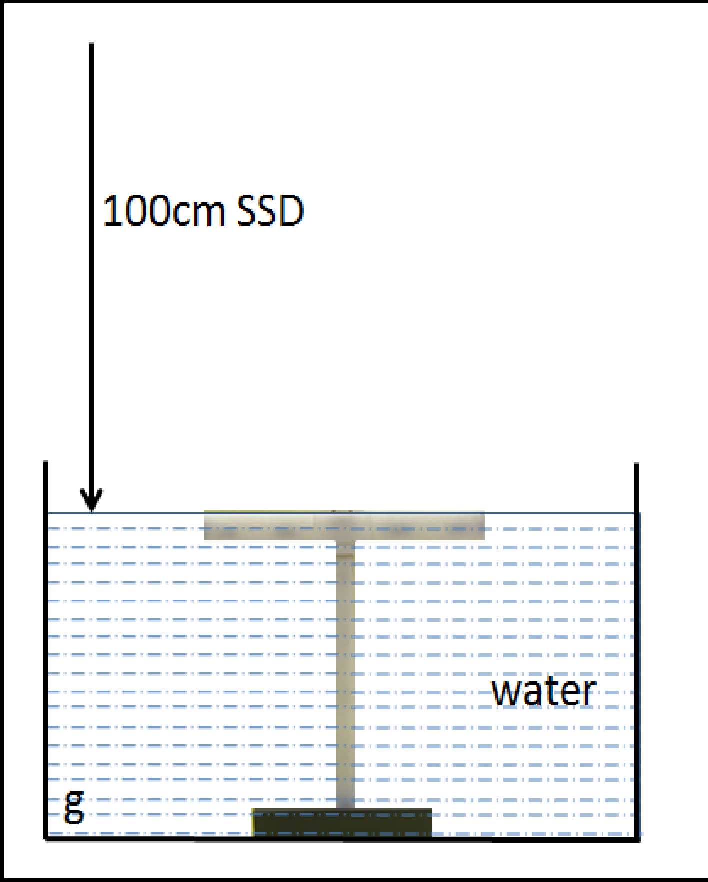
IROC Houston

- Send historic commissioning data to MDACC (no wedges)
- Send patient data to MDACC
  - Initial testing of RPA (10 patients per cancer site)
- Shipping (unless web-based setup)
- Site visit
  - Measurements for DLG and MLC transmission
  - End-to-end tests
  - Workflow verification
  - Training

Radiotherapy Beam Audit Device

- Use together with TLD output checks on as-needed basis





Phantom built at IROC-Houston, with David Followill

End-to-end tests

- Will create tests based on IAEA-TECDOC-1583
- On-site testing

Vision: For end of UH3 Phase (2021)

- At the end of the UH3 phase, we will have deployed to up to 14 treatment centers where the RPA will be used clinically (possibly more if we team with the IAEA).
- Productivity gains
  - At institutions where the physics staff is responsible for the treatment planning, this will translate to a gain in productivity of ~50%.
  - Additional gains from auto-contouring
- Safety gains
  - All head and neck, breast/chest wall, and cervical cancer patients treated at institutions where we deploy the RPA will have thorough secondary QA checks.
- Quality gains
  - All chest wall patients will be treated with optimized plans, reducing acute skin reactions which are correlated with pain and quality of life.
- Further deployment/gains through partnership with Varian

Automation of treatment planning: Summary

- Automatic treatment planning may help reduce the planning burden, reducing staff shortages
- Fully automated cervical cancer 4-field box treatments – almost ready (aiming for January)
  - Field aperture task already deployed at MDA
- Fully automated H/N IMRT/VMAT treatment planning – almost ready (aiming for January)
  - Normal tissue contouring task already deployed at MDA
- Breast / chest wall – next
- (and also work on 2D plans, not mentioned today……)
- Still identifying additional test sites (mostly for phase 2)

Contact: lecourt@mdanderson.org

One big challenge

- Every institution is different –
  - Equipment
  - Treatment approach
  - Staffing (backgrounds etc)
  - Etc.....
- To ensure wide applicability, we need:
  - Collaborators who use digital simulators for GYN
  - People interested in testing our training program (online) and workflow
  - Anyone interested in giving general feedback at certain time points throughout the project