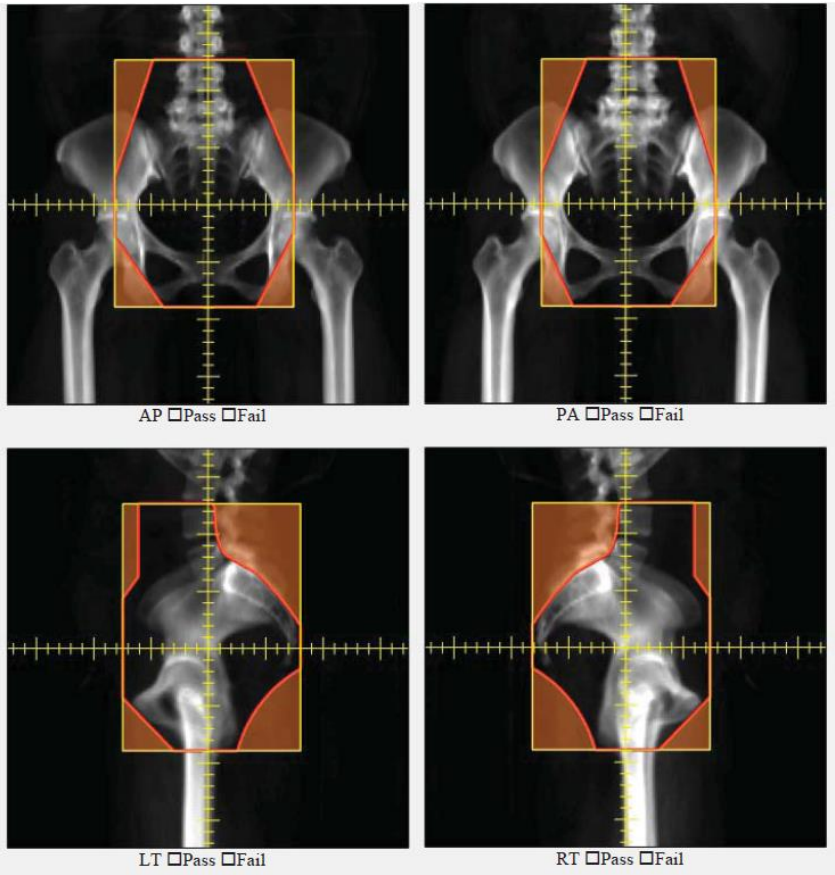
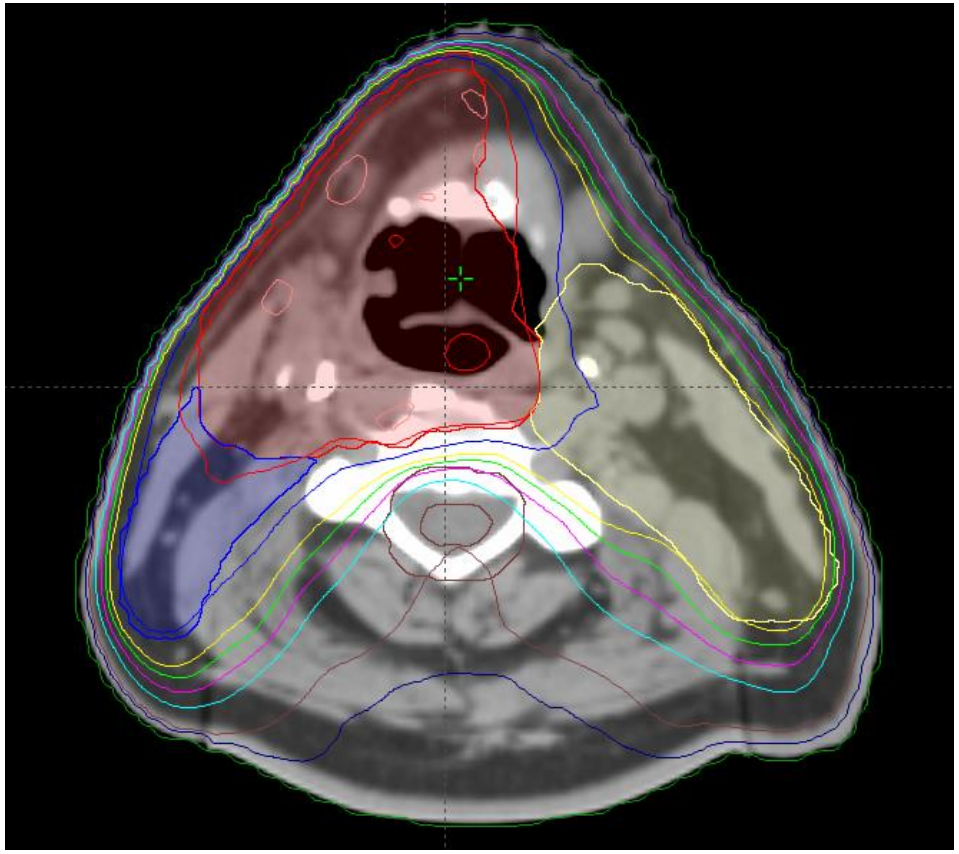
The Radiation Planning Assistant (RPA) for Radiation Therapy Planning in Low and Middle-Income Countries

Laurence Court and team
University of Texas MD Anderson Cancer Center





Disclosures

- This project is funded by the NCI (UH2/UH3)
- Additional technical support + equipment from Varian Medical Systems and Mobius Medical Systems
- Other funding (different projects) from NCI, CPRIT, Elekta

MD Anderson Cancer Center, Houston

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

- Ann Klopp, MD/PhD – GYN planning
- Anuja Jhingram, MD – GYN planning
- Simona Shaitemman, MD – breast

Commercial Partners

- Varian Medical Systems
- Mobius Medical Systems

Primary Global Partners

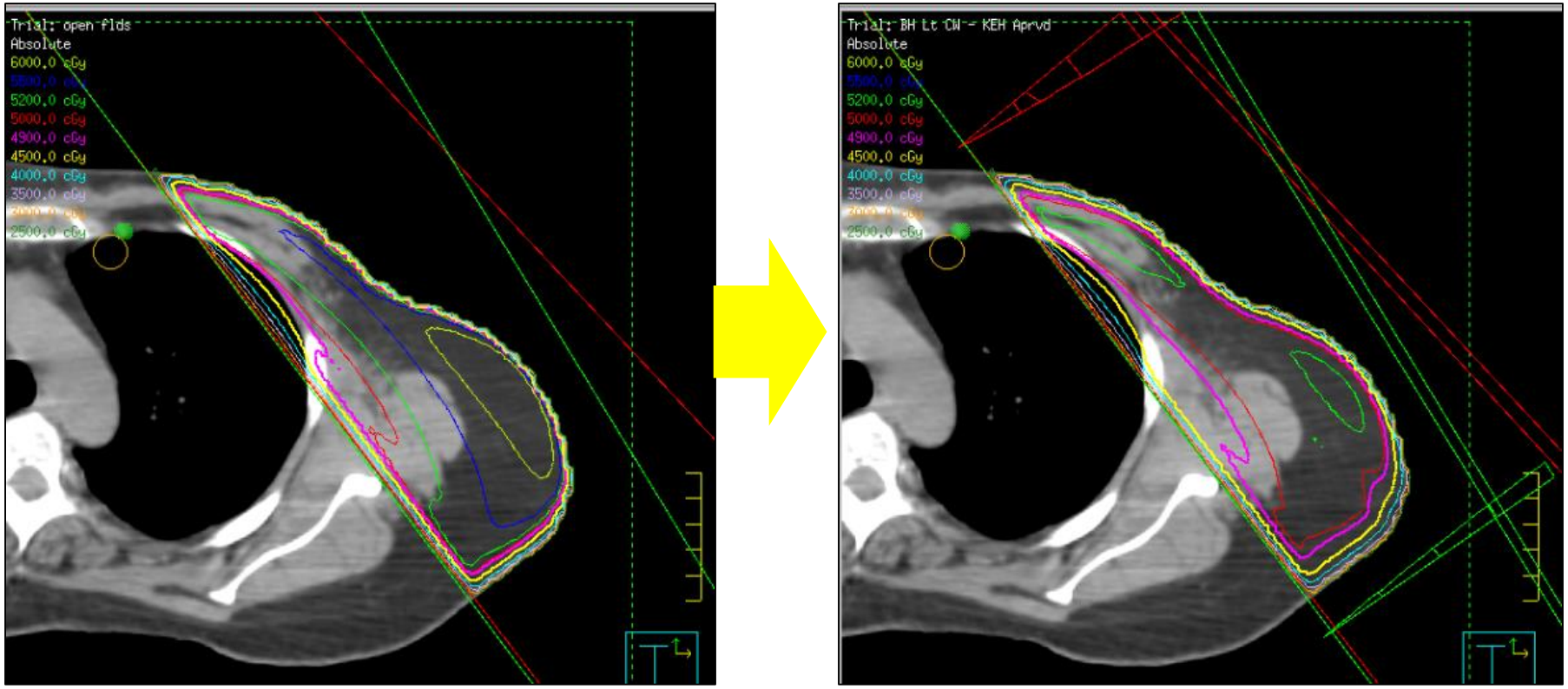
- Stellenbosch University, Cape Town
  - Hannah Simonds, MD
  - Monique Du Toit – physics
  - Chris Trauernicht - physics
  - Vikash Sewram, PhD
- Santo Tomas University, Manila
  - Michael Mejia, MD
  - Maureen Bojador, MS (physics)
  - Teresa Sy Ortin, MD

Global testing sites

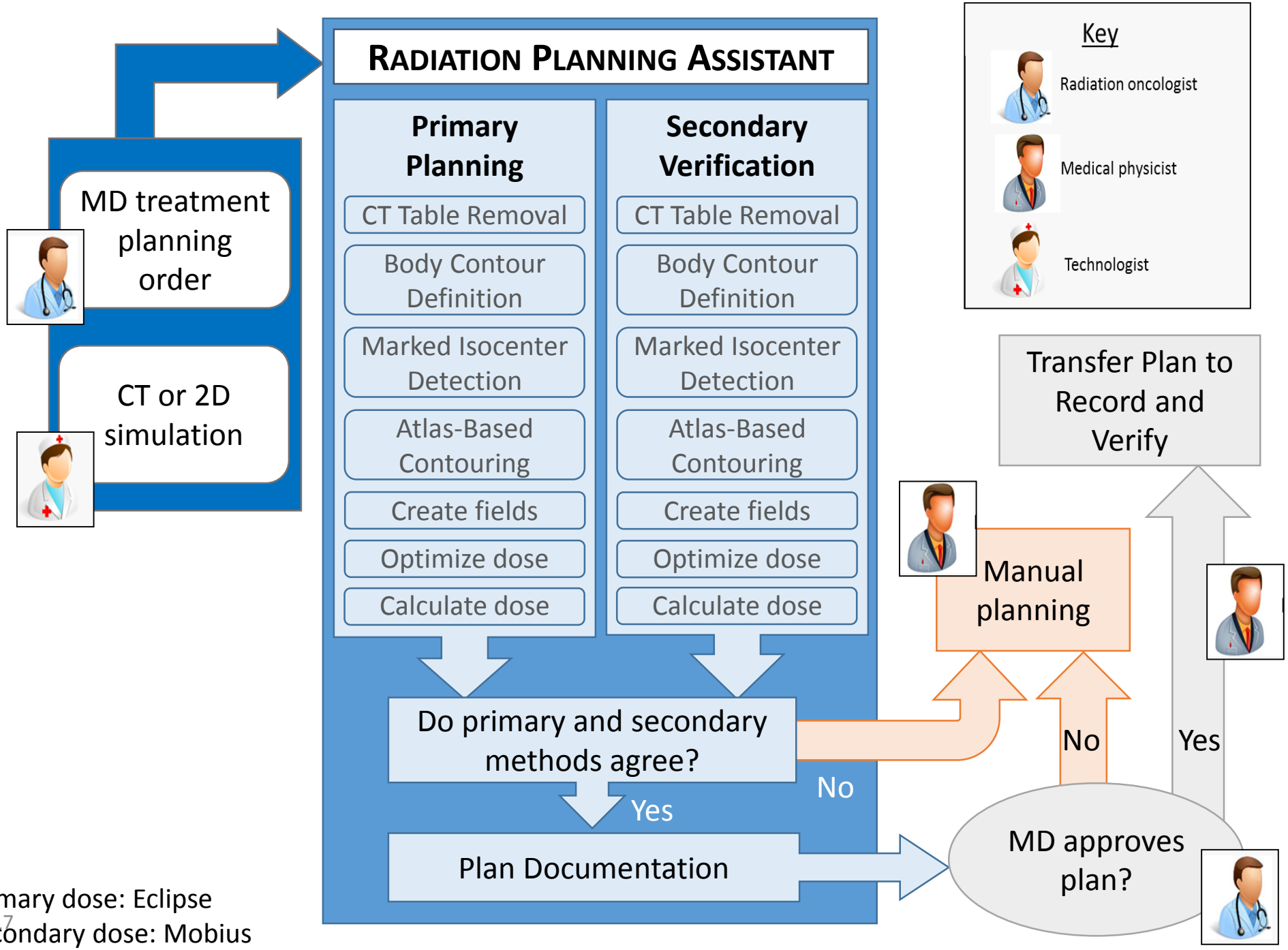
- University of Cape Town
  - Hester Berger, PhD
  - Jeannette Parkes, MD
- University of the Free State
  - William Rae, PhD
  - William Shaw, PhD
  - Alicia Sherriff, MD
- Additional centers

Motivation

- There aren't enough physicists
  - Approximately 50% of physicist time is spent doing treatment planning
- Optimized dose distributions can reduce patient toxicity



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.



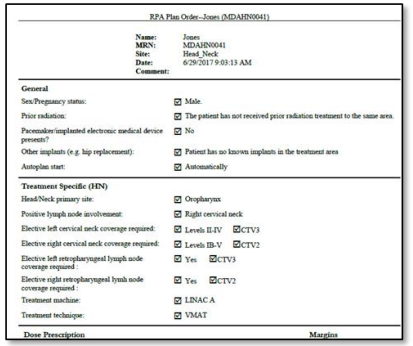
Primary dose: Eclipse
Secondary dose: Mobius

Specific goals of the Radiotherapy Planning Assistant (RPA)

- Automatically create high quality radiation plans for cancers of the:
  - 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.

General philosophy

- Take advantage of Eclipse, but avoid the need for the user to actually use Eclipse
- Use Eclipse functions whenever possible (API)
- Combine with purpose-written tools
- Internal verification for everything
- Work closely with eventual users
- Deploy locally or at central hub
  - Eventually this could/should be cloud based
- Specifically designed documentation



RPA Plan Order--Jones (MDAHN0041)

Name:	Jones
MRN:	MDAHN0041
Site:	Head_Neck
Date:	6/29/2017 9:03:13 AM
Comment:	

General

Sex/Pregnancy status:	☑ Male.
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 (HN)

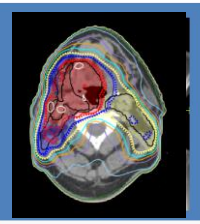
Head/Neck primary site:	☑ Oropharynx
Positive lymph node involvement:	☑ Right cervical neck
Elective left cervical neck coverage required:	☑ Levels II-IV ☑CTV3
Elective right cervical neck coverage required:	☑ Levels IB-V ☑CTV2
Elective left retropharyngeal lymph node coverage required :	☑ Yes ☑CTV3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

Dose Prescription	Margins

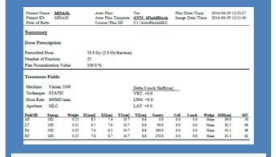
Plan Order

CT image

RPA



Radiotherapy treatment plan



Documentation

Feedback and development

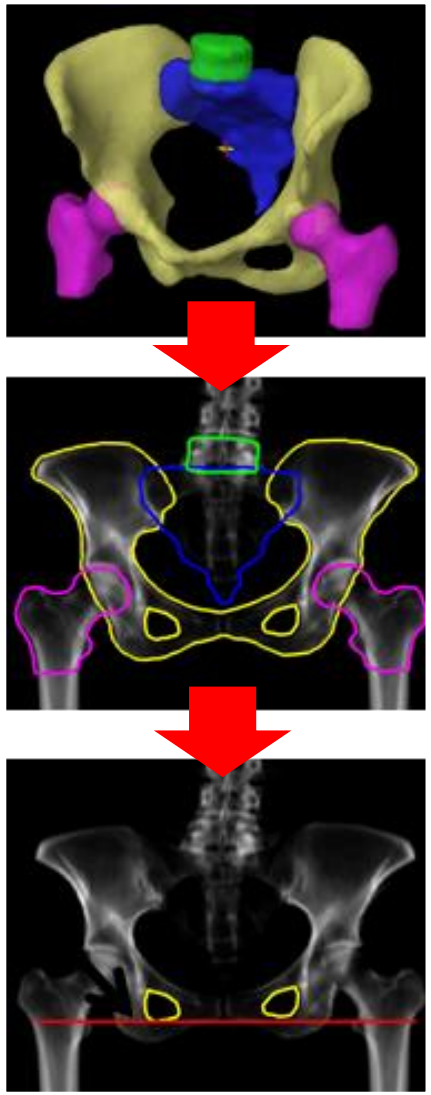
Extensive and continual clinical feedback is a key factor in this project

- Feedback and interaction with radiation oncologists at MD Anderson, South Africa and the Philippines
  - Continual feedback from MDACC radiation oncologists
  - Monthly feedback from primary partners (South Africa and the Philippines)
  - Specific feedback from wider partners

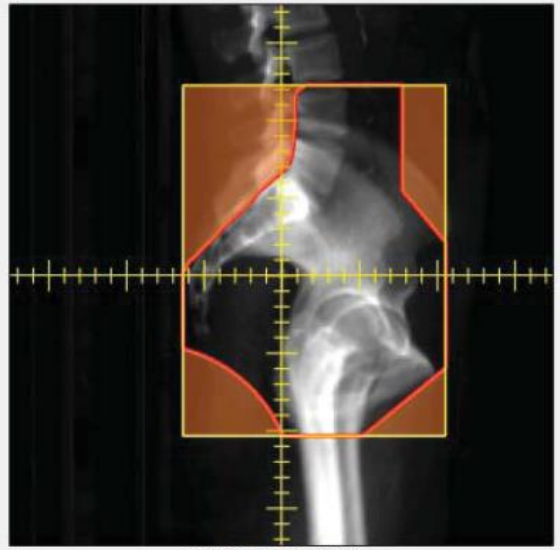
- Clinical deployment at Anderson
  - Head/neck normal tissue autocontouring deployed at MD Anderson since 2016, ~250 patients so far
  - Cervical cancer field apertures deployed at MD Anderson since June 2016, 22 patients so far

- Full clinical deployment at LMIC partners (next year)

Current status: Cervical cancer treatment plans



- Fully automated plans working, including apertures, dose calculation, field weight optimisation
- Acceptable 4-field box plans ~21minutes
- Tested on total 400+ unique patients
- Reviewed by physicians from MD Anderson (USA) and Stellenbosch University (South Africa)
- Most recent version
  - n = 150
  - 89% Approval Rate
  - #1 cause of rejection: superior border
  - **Otherwise, 99% of plans are acceptable**
- Aperture creation deployed to MD Anderson clinic
- Verification: 2 methods – (1) 2D registration, (2) deep-learning

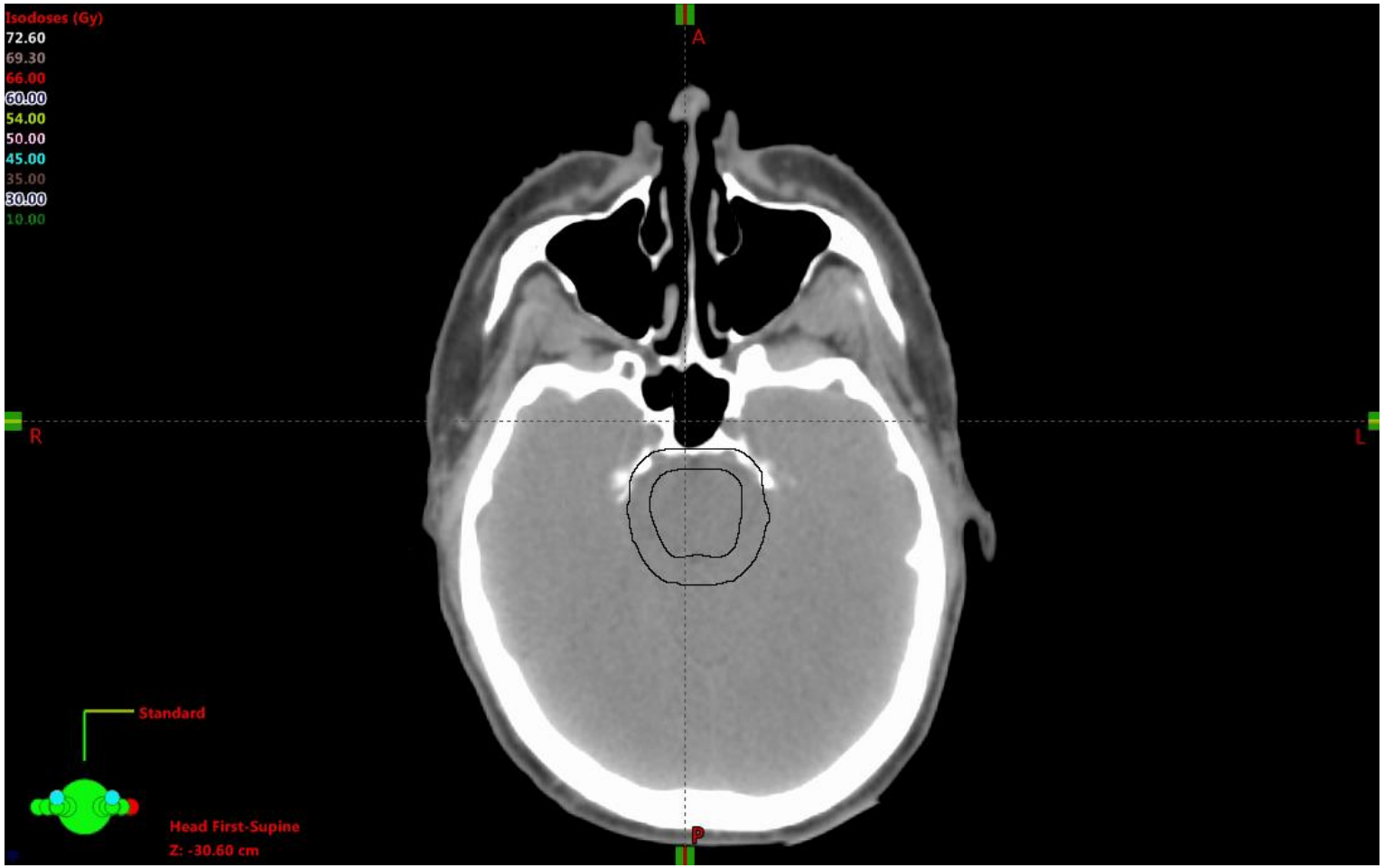


Iterations of testing

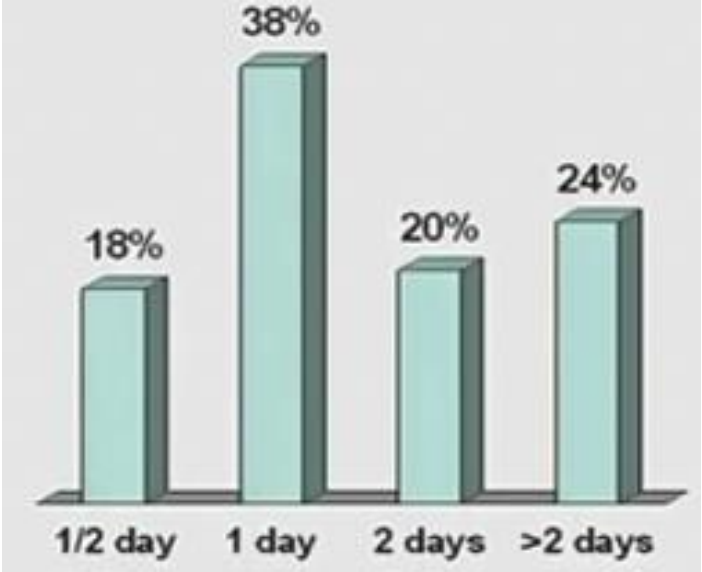
Tested on 469 unique patients!

Feb 2016	**Initial Test (v1)**	n = 39 patients	Reviewed by MDA physician
Jun 2016	**MD Anderson clinical implementation (vMDA.1)**	n = 18 patients	Compared beams after physician edits
Dec 2016	**2nd physician review of initial test (v1)**	n = 39 patients	Reviewed by Tygerberg physician
Jan 2017	**Test on 1st set of Stellenbosch patients (v2)**	n = 9 patients	With clinical target contours
Jan-Feb 2017	**1st large test of full automation (v3)**	n = 228 patients	Reviewed by MDA physician
Mar 2017	**2nd large test of full automation (v4)**	n = 150 patients	Reviewed by MDA and Tygerberg physicians
Apr 2017	**Test on 2nd set of Stellenbosch patients (v4)**	n = 8 patients	With clinical target contours
May 2017	**MD Anderson clinical implementation (vMDA.2)**	n = 3 patients (as of Sep 2017)	Compared beams after physician edits
Sep 2017	**Onsite test - South Africa (v5)**	n = 23 patients	Reviewed by Groote Schuur and Tygerberg physicians

Head and neck planning



Time for IMRT planning for a complex case (excluding contouring)

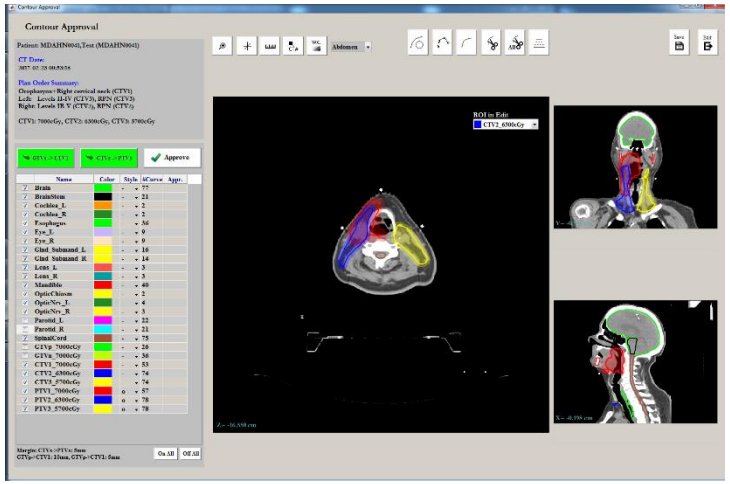


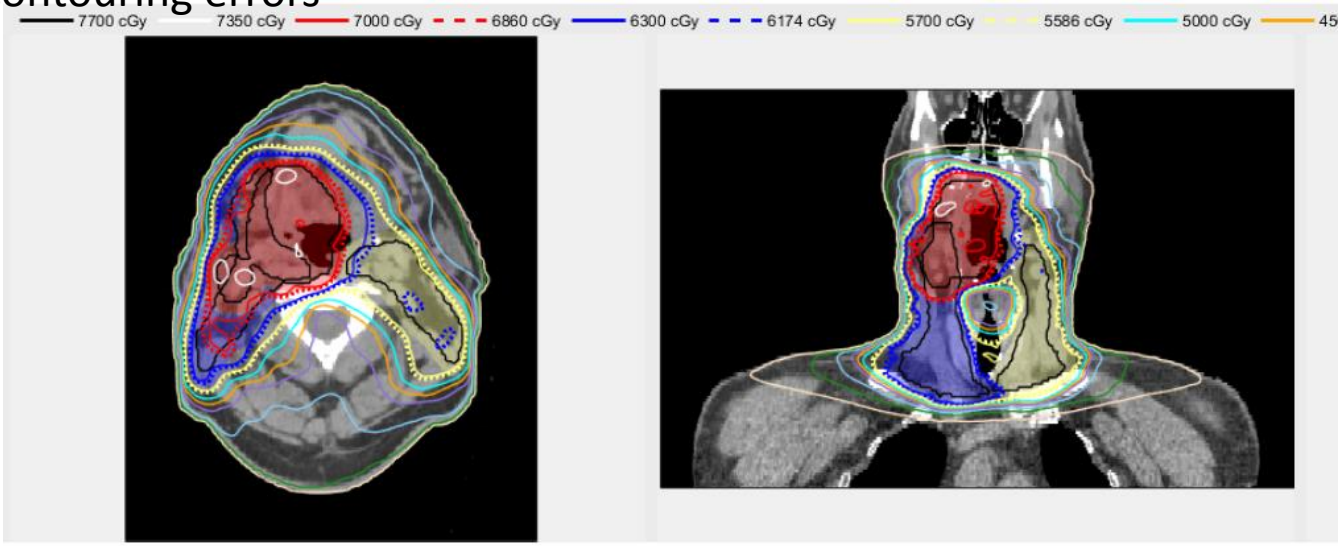
N=167, ASTRO 2004

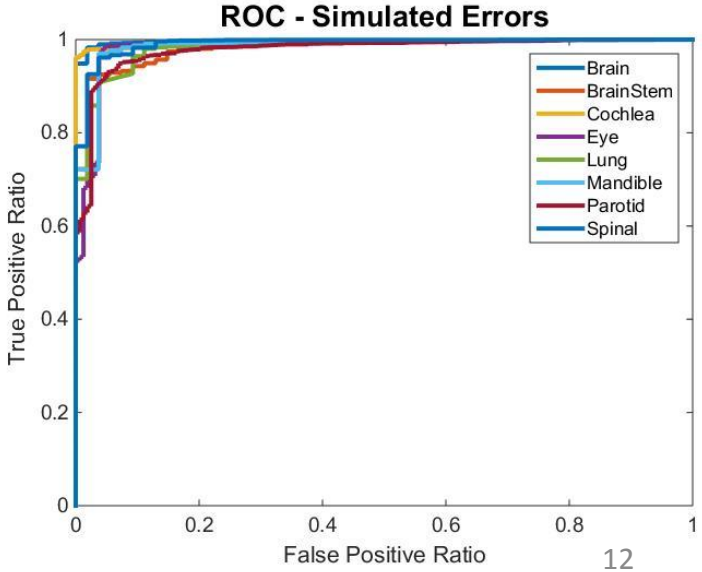
Current status: Head / neck VMAT plans

- We now have clinically acceptable single-shot plans (~45 minutes)
- Radiation Oncologist delineates the GTV – everything else is automated
  - Nodal level contouring
  - Normal tissue contouring
  - Plan optimization
  - Internal QA

  } Multi-atlas contouring (in-house)
- Normal tissue contouring deployed at MD Anderson (250+ patients)
- **100% of plans have been approved by rad oncs (small n)**
- Machine learning tool for predicting contour quality –effective at detecting contouring errors





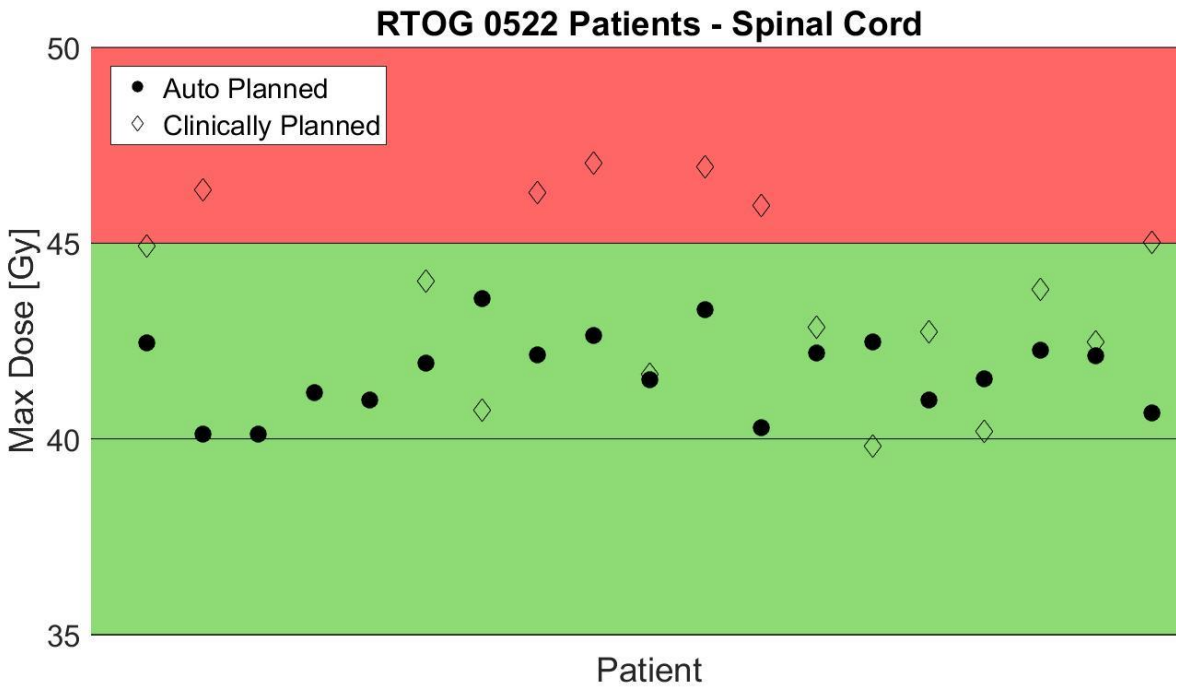


Validation of Autoplanning

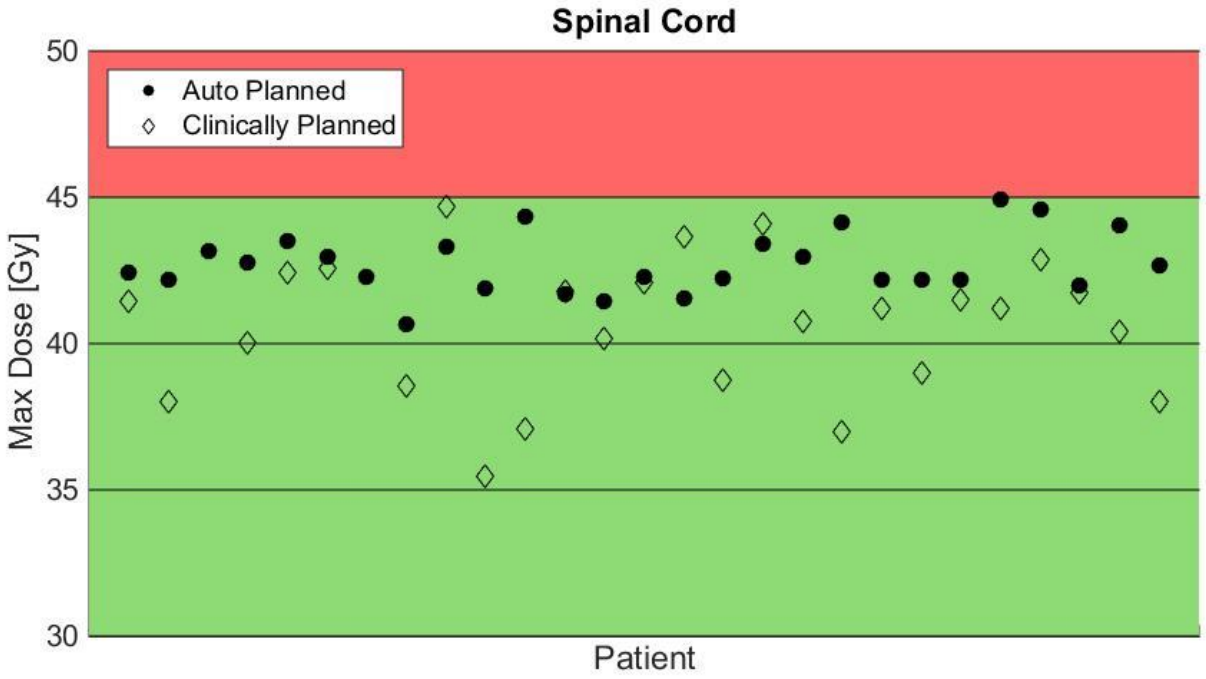
- RTOG 0522 - A Randomized Phase III Trial of Concurrent Accelerated Radiation and Cisplatin versus Concurrent Accelerated Radiation, Cisplatin, and Cetuximab (C225) [Followed by Surgery for Selected Patients] for Stage III and IV Head and Neck Carcinomas
  - Only IMRT patients chosen for this analysis (19 patients so far)
  - $PTV_{HighDose}$: 35x2Gy=70Gy
  - $PTV_{ElectiveDose}$: 35x1.6=56Gy
- MDACC clinical cases
  - 30 patient, mixed stage head and neck carcinomas
  - VMAT cases chosen for this analysis (30 patients)

Validation of Autoplanning - Results

a. Comparison with RTOG0522



b. Comparison with MDACC clinical cases

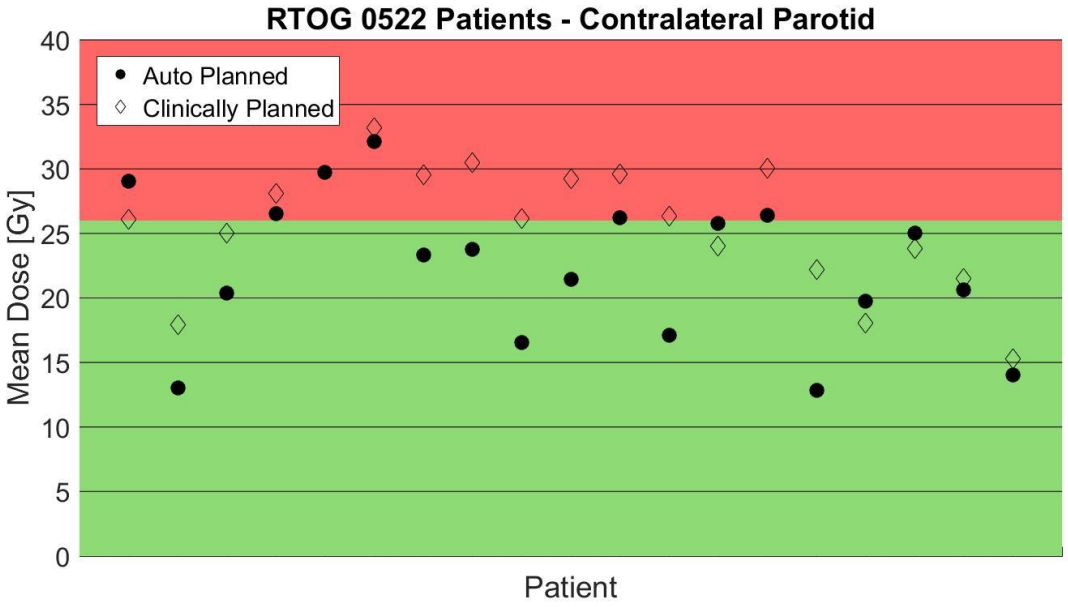


Per Protocol

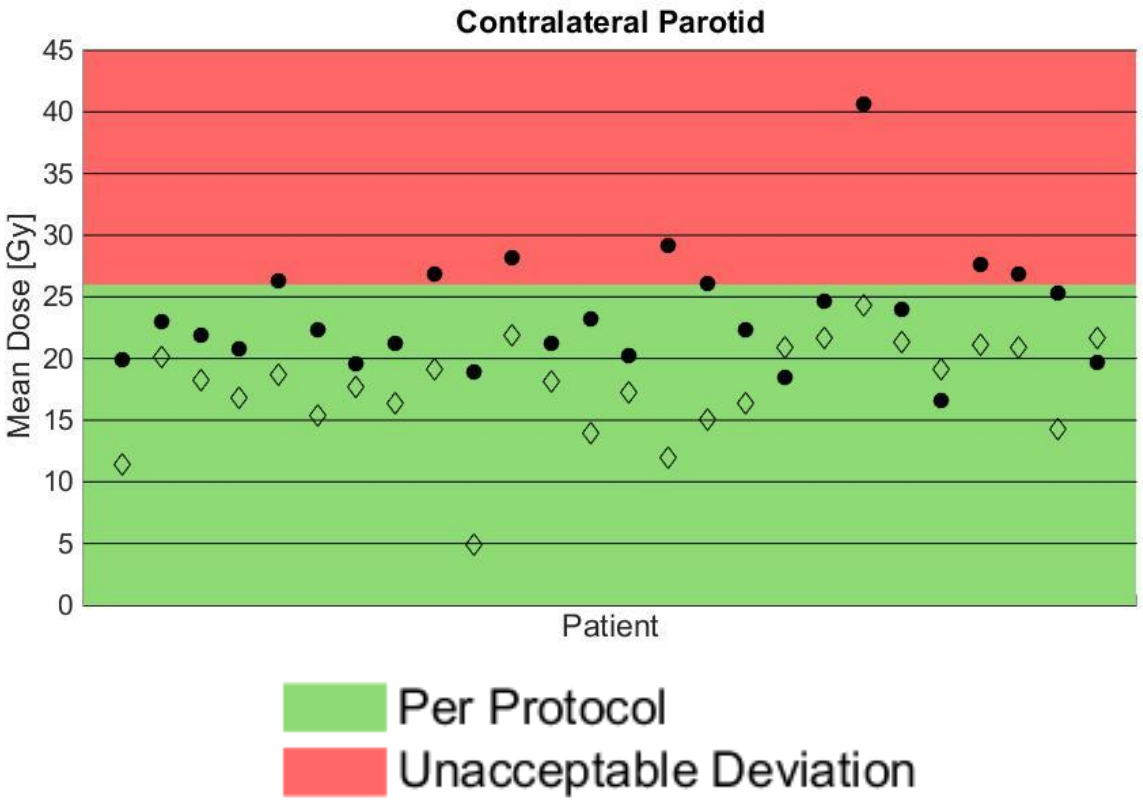
Unacceptable Deviation

Validation of Autoplanning - Results

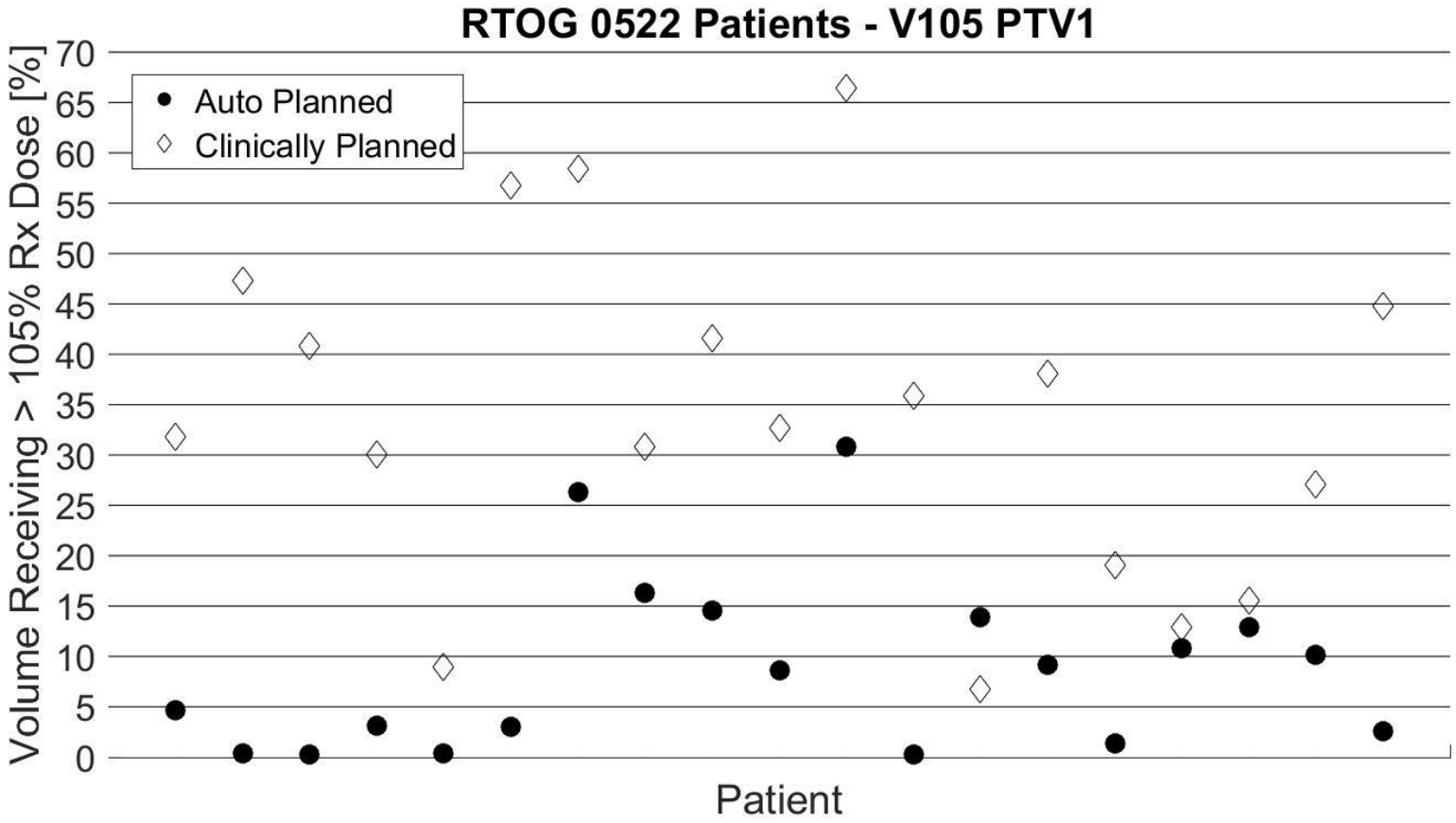
a. Comparison with RTOG0522



b. Comparison with MDACC clinical cases



Validation of Autoplanning - Results



Feedback at the International Conference on Advances in Radiation oncology (ICARO2), IAEA, 20-23 June 2017

RPA impact question (head/neck cancer): Based on these examples, would you use RPA for planning head/neck treatments?

A.	Yes	67%
B.	I would like to, but do not have the right equipment (CT scanner, VMAT-capable LINAC)	21%
C.	No - the plans do not have sufficient quality	13%
D.	No – other reason	0%

Total votes: 24

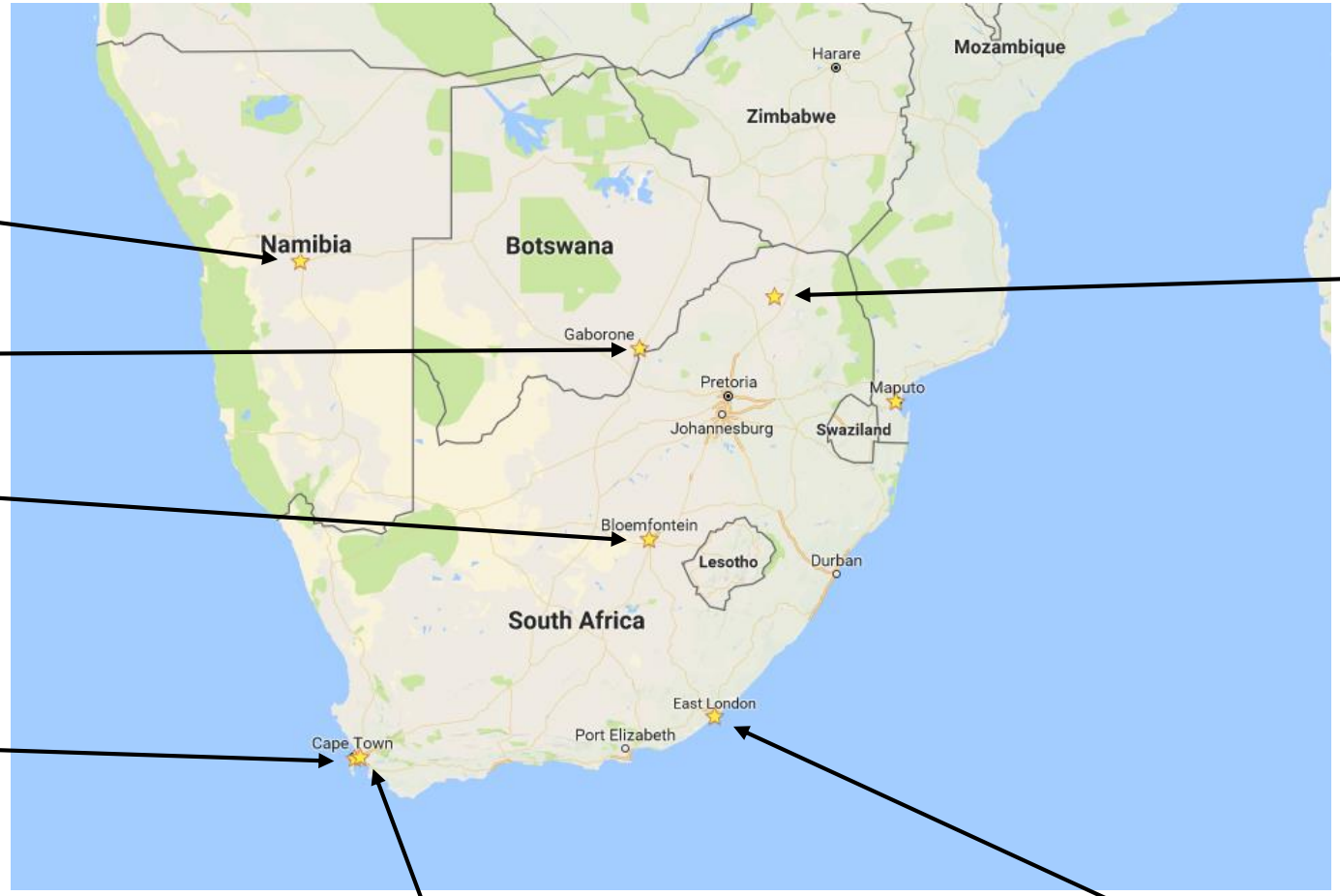
- Participants were mostly European
- Head/neck (3 plans on slides):
  - Wide acceptance of head/neck VMAT (76% of people with appropriate equipment)
- Cervix (2 plans on slides):
  - 25% approval for 4-field box approach
  - The majority of participants use 3D conformal, IMRT or VMAT treatments

RPA impact question (cervical cancer): Based on these examples, would you use RPA for planning cervical cancer treatments?

A.	Yes	25%
B.	I would like to, but we do not have the appropriate equipment (CT or MLCs)	4%
C.	No – we base our treatments on contoured targets and normal tissues	64%
D.	No – there is no benefit for us	4%
E.	No – other reason	4%

IAEA
International Atomic Energy Agency
Atoms for Peace

South African Partners



Windhoek

Gaborone

University of the Free State

Groote Schuur Hospital, University of Cape Town

Tygerberg Hospital, University of Stellenbosch

Limpopo

East London

South Africa data trip, September 2017

- Laurence Court, Kelly Kisling and Rachel McCarroll visited SA for a week
- 3 days at Tygerberg and 2 days at Groote Schuur
- Collected patient data for planning

Tygerberg Hostpital, Stellenbosch University

- **Cervical cancer treatments**
  - Collected 33 patient CTs
  - Ran 10 cervical cancer patients through the RPA and reviewed with Dr Simonds (~1hour)
    - She approved all 10 plans
- **Head/neck treatments**
  - Collected 22 patient CTs
  - Ran 5 H/N patients through the RPA and reviewed with Dr. Naidoo
  - Spent ~90minutes carefully reviewing these 5 RPA plans
  - She approved all plans – sees advantage in coverage and normal tissue dose

South Africa data trip, September 2017

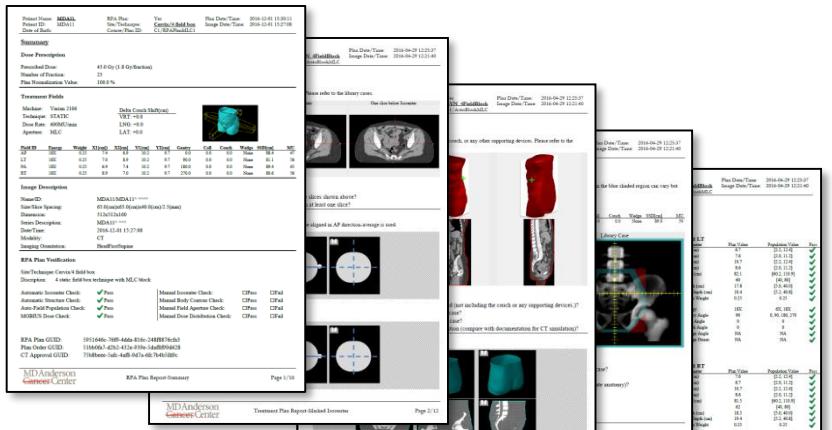
Groote Schuur Hosptial, University of Cape Town

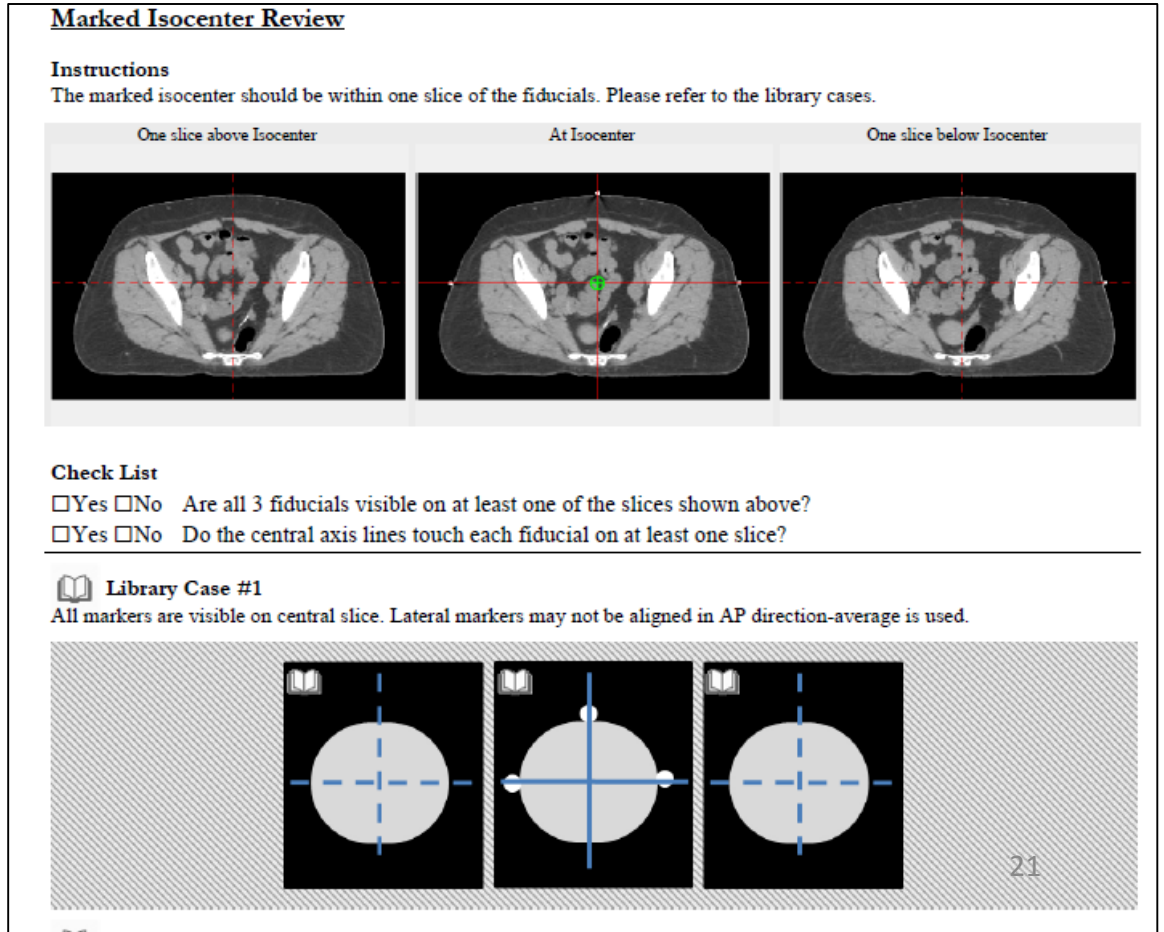
- **Cervical cancer treatments**
  - Collected 13 patient CTs
  - Ran 13 cervical cancer patients through the RPA and reviewed 4 with Dr Fakie (+2 residents) ~1hour
    - She approved all 4 plans
    - The resident (Kenyan) said they are typical of the plans used in Kenyan clinics
- **Head/neck treatments**
  - Collected 10 patient CTs
  - Reviewed 3 Tygerberg patient RPA plans with Dr. Wetter
  - Spent ~2½ hours carefully reviewing these RPA plans
  - She approved all plans
    - “would treat this plan as is”
    - “can’t complain at all”
    - “no way to find fault”

Summary of current status of the RPA project

- ☑ Fully automated head/neck plans
- ☑ Fully automated cervical cancer plans
- ❑ Finalizing integration with Eclipse and larger scale, formal testing/feedback
- ❑ Chestwall – Goal is to complete by year-end

- ❑ Enter Clinical Evaluation phase in May 2018
  - (if funding is confirmed)
  - First deploy at Tygerberg, Groote Schuur and Santo Tomas
  - Then add Bloemfontein
  - Then East London, Limpopo, others….. (TBD)





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?

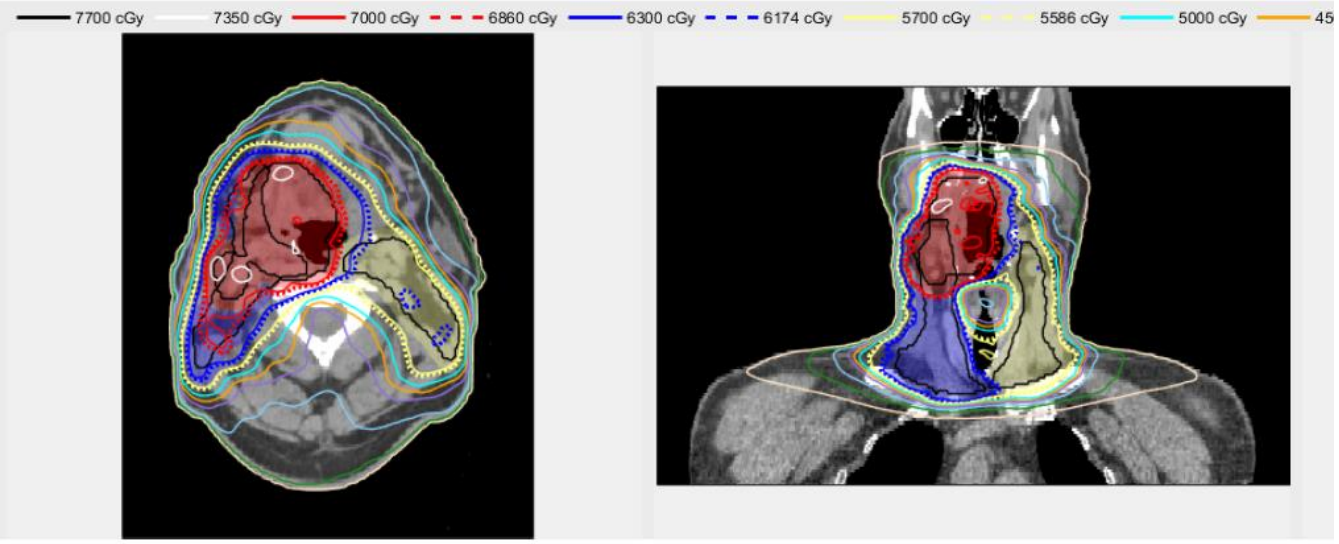
☐Yes ☐No Do the central axis lines touch each fiducial on at least one slice?

Library Case #1

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

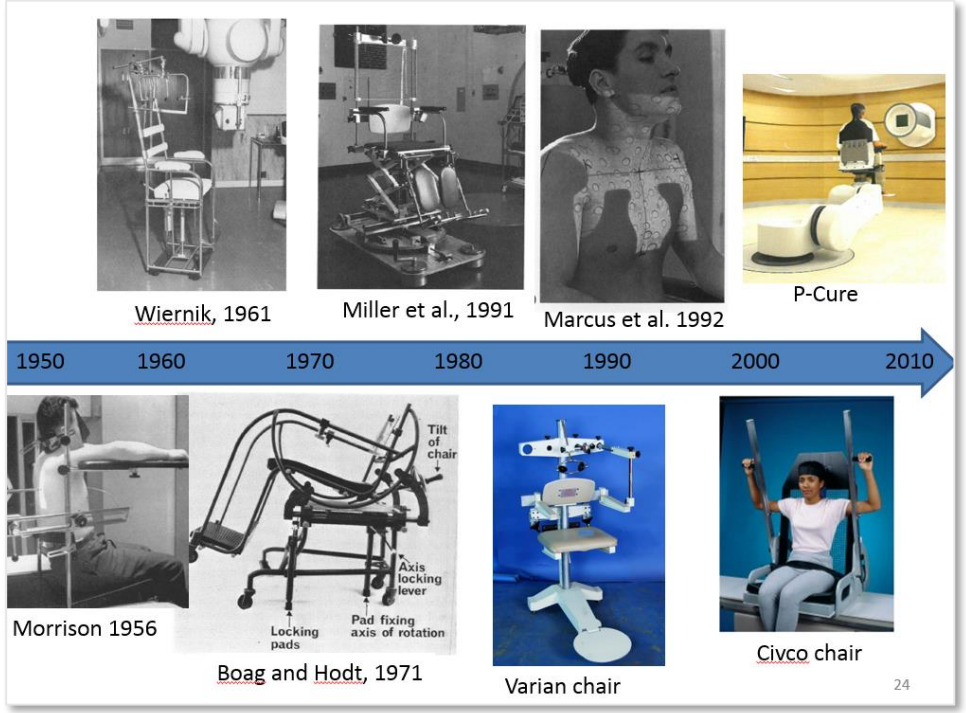
In the context of this workshop

- Automated treatment planning is essential
- Automated treatment planning is possible
- Continual feedback from eventual users is vital
- Additional software QA is also important



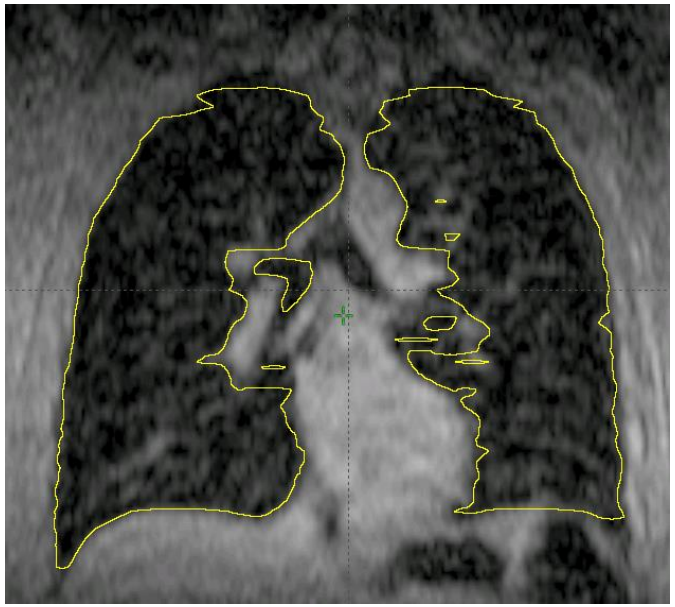
Treatment chairs:

- Have clinical support
- Can be clinically beneficial
- Have a long (mostly forgotten) history



Practical Radiation Oncology (2014) 4, e53–e58

Supine setup position



Upright setup position

J Appl Clin Med Phys 2017; 18: 223–229