Review and guidelines for treating head and neck tumors using IMRT and VMAT

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Chuck Mayo
Educational Objectives:

• Discuss the issues surrounding plan evaluation: Variability in target definition, prescriptions, margins, etc.

• Discuss different approaches for the use of IMRT for treating head and neck tumors

• Describe the use of VMAT to treat head and neck tumors

• Comparison of VMAT and IMRT for head and neck tumors
Variability in planning criteria and plan evaluation

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• Target / prescription variability
• Contouring variability
• Margins
• Coverage / hotspots
Acknowledgements

• Roy Tishler, DFCI
• Indra Das, Indiana University
• Martin Murphy, Virginia Commonwealth University
• Wolfgang Tomé, University of Wisconsin
• Debbie Schofield, Baptist Cancer Institute
• Chuck Mayo, Mayo Clinic
Variations in CTV Design

T2 N1 M0 Tonsil Cancer

Primary Tumor

Neck Node

Theodore S. Hong, Wolfgang A. Tomé, Richard J. Chappell, and Paul M. Harari
University of Wisconsin
AAPM 2010
Bilateral vs. Ipsilateral

- Ipsilateral: 15.8%
- Bilateral: 84.2%

Elective CTV Design

- Single level: 36.8%
- Multiple levels: 63.2%

TS Hong et al. AAPM 2010
Contouring variability

- 5 trained residents contoured all nodal levels
- RTOG consensus guidelines

CTV+3mm
CTV+5mm
CTV+7mm

AAPM 2010
Effect of contouring on target dose

Data from Lu et al, VCU (Martin Murphy)
PTV=CTV+ (3 - 5mm)
Effect of contouring on parotid dose

Data from Lu et al, VCU (Martin Murphy)
Margins

- PTV expansions to account for setup
  - Mean: 4.1 mm (Hong et al)
  - Range: 0-15 mm
  - UMass: 3-5mm, MDACC: 3-4, DFCI: 3-5mm, Mayo: 3mm
  - MD draws PTV

- Use of optimization structures

- Pull back from skin (3-5mm)
  - DFCI: 3mm (PTV),
  - UMass: 4mm (IMRT PTV)

- Planning Risk Volume: 0 – 10mm
  - Cord: 5mm (MDACC, MNCJAX), 7mm (DFCI), 1cm (UMass) [3cm posterior]
  - Optic nerves: 3mm (DFCI and UMass)
  - Parotid: 0mm
Target coverage

• 100% PTV covered by 100% (Mayo)
• 95% of PTV getting 100% prescription, ‘most’ covered by 98% isodose (DFCI)
• 99%+ CTV covered by 100% (MDACC)
Hotspots

- 105%+
- DFCI: Aim for 5%, <110%
- UMass: aim for <110%. Typically 8% vol < 10% (will accept ~10% of PTV > 110% if necessary)
- 105-110% (MDACC)
- MGH: 110-115%, 120%+ if necessary
- Impact of chemotherapy
Variations in minimum and maximum dose

Indra Das et al. J Natl Cancer Inst 100 (5), 300-3007, 2008
(209 H&N patients)

AAPM 2010
Impact of how dose is reported

- 1cc or point dose
- Definition of PTV

DFCI data

AAPM 2010
Summary

• H&N IMRT (or VMAT) planning is remarkably heterogeneous
  – Contouring
  – Margins
  – Prescription, including coverage and hotspots

• Care needed when comparing data from different clinics
The Use of IMRT in the Treatment of Head and Neck Cancer

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Immobilization and Localization

Treatment Planning Tips
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Roy Tishler, MD, PhD – Dana Farber
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Immobilization

The H&N region allows for excellent immobilization and localization

Thermoplastic Mask: “standard”

Head Rests: Standard cups or custom forms

Bite Blocks: Consider for certain cases (oral tongue, floor of mouth, hard palate)
Notes of Caution:

(1) Good Immobilization does NOT always equal good localization

(2) Continuous evaluation of immobilization performance throughout the treatment
Localization

Verification of localization can be accomplished with orthogs

For MV Imaging, the dose delivered during daily imaging can be accounted for and included in a final plan sum and DVH’s.
Study at DF/BWH Cancer Center retrospectively evaluated patient setup based on daily ports (Court, et al, JACMP, 9(3), 2008)

Isocenter: within 3mm for a median of 92.5% patients.

Shoulders: 30% of repositioning involved shoulder shifts $\geq 1$cm!
20% patients required $\geq 1$ cm shoulder shifts for 7/35 fraction same direction/patient
Example of Shoulder Shift

Good Agreement at Iso

7mm Shoulder Shift

1.38 cm [SAD]

2.10 cm [Actual]
Overview

- Immobilization and Localization

- Treatment Planning Tips
  - Routine Cases
  - Extended Disease
  - Sinus
  - Retreatments
Routine Cases

- Typical plan consists of 7 – 9 beam angles

- The beams do not need to be evenly spaced. Instead they should be based on a critical evaluation of patient anatomy and target geometry

- Beams should avoid (fixed jaws):
  - Entering through bite blocks
  - Shoulders
  - Compressed shoulder area on larger patients
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How to Treat the S/C

Four possible approaches:

1. Treat full extent with IMRT
2. Single isocenter IMRT matched to LAN
3. IMRT matched to a stepped wedge LAN (UAB Technique)
4. Larynx sparing extended field IMRT
Full Field IMRT

- No matchline issues
- Excellent coverage of deep seated neck nodes
- Increased dose to the uninvolved larynx
- Brachial plexus
Single Isocenter Matched to Static LAN Field

- IMRT in the superior region
- LAN field for inferior region
- Limitations in the field size (Nasopharynx)
- In homogeneities at matchline
- Study from Wash U, found that 19% of their failures occurred at the matchline*

IMRT Matched To A Stepped Wedge LAN Field (UAB Technique)

- Stepped wedge approach in the superior 3cm of LAN
- External program generates stepped wedge feature
- Single LAN can’t treat deep seated S/C nodes

Larynx Sparing IMRT (DFCI)

- AP/PA type fields treat disease at/below larynx - split into LT and RT components
- Inferior edge of other beams are fixed at the top of the larynx
- No field Size limitation or matchline issues
- Can treat deep seated nodes
Larynx Sparing IMRT*

Overview

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Differential Smoothing IMRT for Thyroid/H&N Disease with extension into Mediastinum*

Low smoothing
- yields more complex fluence
- smaller leaf gaps

High Smoothing
- yields less complex fluences
- larger leaf gaps
- not as conformal for complex geometries
- less susceptible to interplay effects

Planning Strategy

Single Isocenter

Neck:
- 7-9 low smoothing rate beams
- 5mm PTV expansions

Mediastinum:
- 3-4 high smoothing rate beams
- PTV expansions based on respiratory motion
Lung Doses
MLD: 11.9Gy
V20: 20.5%
V5: 49.8%
Overview

- Immobilization and Localization

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  - Retreatments
Sinus / Nasal Cavity

- This site can be difficult to treat because of the proximity of the target volumes to the optic structures.

- OAR’s
  - Globes and Optic Nerves
  - Chiasm
  - Lacrimal glands
  - Brainstem
Technique

Gantry Angles:  $90^\circ, 270^\circ$

Couch:  $0^\circ$

Gantry Angles:  $340^\circ, 0^\circ, 30^\circ, 60^\circ, 90^\circ$

Couch:  $90^\circ$

IMRT for paranasal sinus and Nasal Cavity Tumors. Duthoy and De Neve, ‘IMRT for paranasal sinus and nasal cavity (sino-nasal) tumors’, Image Guided IMRT
Example

Sharp Dose Gradients

Rx: 6000 cGy
Overview

- Immobilization and Localization

- Treatment Planning Tips
  - Routine Cases
  - Extended Disease
  - Sinus
  - Retreatments
Retreatments

- Retreatments are difficult
- Often have to deliver high dose (>50Gy) in close proximity to OAR’s that have already received (up to) tolerance dose
- Often need high number of beam/couch angles
- Use fixed jaws to protect OAR’s
- Cord / expanded cord dose limits:
  - Cord: 10-12Gy
  - Expanded cord: 15Gy
Example: Sinus Retreat

Patient had been previously treated to the sinus

Optics: Previously treated to Full tolerance

Recurrence: ~ 1yr after radiation
GTV ~ 2mm from optics
Beam Configuration

11 Beams, 7 couch angles

Fixed Beams
For Optimization

3mm margins on Optics

Sup dummy “PTV” pulled away from optic structures

Unmodified inferior PTV
Results

Dose fall off: 50Gy to 20 Gy < 1cm
Educational Objective

Discuss different approaches for the use of IMRT for treating head and neck tumors.

We discussed:
- immobilization and localization
- routine cases including 4 approaches for the treatment of the S/C
- H&N with extension into the mediastinum
- sinus
- re-irradiation
Review and guidelines for treating head and neck tumors using IMRT and VMAT

Volume-Modulated Arc Therapy

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WE-B-203-1
Wednesday 8:30 am -9:25 am Room 203
Disclosure

• Grant support from Varian Medical Systems
Outline

• Brief review of VMAT
• Advantages / disadvantages of VMAT vs. IMRT
• Tips on planning VMAT cases
• Comparison of VMAT and IMRT plans (including some special cases covered in IMRT portion)
• Table attenuation correction
• QA for RapidArc (? Depends on time)

Where we thought the challenges would lie and where they actually did emerge.

The Learning Curve

Probability of getting the desired plan

Moving from here to here
What is Volumetric Modulate Arc Therapy (VMAT)?

- IMRT modulates MLC’s during beam on to shape the 2D beam profile on a fixed angle beam. Combine beams for a 3D dose distribution.

- VMAT modulates MLC’s, gantry speed, dose rate during beam on to shape the 3D dose distribution from arc beams.

- Available in most treatment planning systems
  - Eclipse (RapidArc) examples in this presentation
  - Pinnacle (Smart Arc)
  - CMS (Monaco with VMAT)
Why VMAT?

• Fewer Beams
  • 2-3 Arcs vs 9-18 (carriage splits)

• Improves QA process
  • Improves 2\textsuperscript{nd} check process on plans
  • Reduces time for QA measurements

• Shorter Treatment Time
  • Patient satisfaction
  • Reduced potential for intra-fraction motion
  • Better utilization of FTE and technology resources
  • Create more available time for IGRT
Why VMAT?

- Potential for improved planning
  - Arc distributions help reduce intermediate dose level exposures.
  - Difficult to over modulate a RapidArc beam. Less likely to fail in QA measurements when normal tissue constraints are pushed.
  - Templated approach to planning that may raise the bar on base plan quality.
Basic planning approach: we use the same **contouring based** approach to planning for RapidArc that we developed and reported for IMRT many years ago.

- **CTV**
- **PTV**
- **IMRT PTV**
  - Optimize on the IMRT PTV
  - Margin to compensate for shoulders on profile
  - Modify to reflect normal tissue compromises

**Dose Limiting Annulus**
- To control intermediate dose levels

**Normal Tissue to Avoid**
- Contour actual anatomy
- Add separate buffer structures as needed

In several of the clinical examples to follow you will see extensions of this basic contour orient approach to planning.
Dose Sculpting Structures

- **PTV 54 Gy**
- **PTV 60 Gy**

**IMRT PTVs** are cropped back from surface by 4 mm.
- Optimize to IMRT PTV
- Normalize/Evaluate PTV

**DLA:** Defines intermediate dose region for dose reduction

**Buff:** Specifies sub-region between target volumes to drive out “hot” spots

Charles Mayo, Ph.D.
Contouring – Targets

Overlap at junction

GTV
CTV
PTV
IMRT-PTV

Overlap at junction
Contouring – Targets
Fix with IMRT PTV

Crop IMRT PTVs in overlap region to reflect which gets the higher priority for coverage. More intuitive than trying to do this in the optimizer with overlapping structures.
Normal Structures

It is important to try to contour the actual anatomic structures, in order to make meaningful comparisons of normal tissue constraints or complications.

Use buffer or sculpting structures to control dose gradients.
Contour normal structures to be anatomically correct. Include a buffer on normal tissues to control gradient of dose near to normal tissue.

Contour cord, not spinal canal. Use cord buffer structure in optimization to control gradient near cord.
For dose painting (e.g. 60 Gy and 54 Gy targets) two DLA’s may be helpful.
Beam Selection

Fields
- Setup KV R Lat
- Setup KV AP
- 1 RA CCW
- 2 RA CCW
- CCBT
- T1 Trilogy - 6X
- Varian EEC
- MLC

Dose Prescription
- 270.0 0.0 0.0 None 15.0 ±7.5 ±7.5 22.0 ±9.0 ±13.0 0.2 -2.7 -6.3 94.0
- 175.0 30.0 0.0 None 15.0 ±7.5 ±7.5 22.0 ±9.0 ±13.0 0.2 -2.7 -6.3 92.0
- 340.0 30.0 0.0 None 15.0 ±7.5 ±7.5 22.0 ±9.0 ±13.0 0.2 -2.7 -6.3 95.0

Plan Objectives
- Optimization Objectives
- Dose Statistics
- Calculation Models
- Plan Sum

MAYO CLINIC
Beam Selection
Control Points

Get other beam 126 vs 177
Beam Selection
Two Dose Levels (60Gy/54Gy)

1) Clockwise
2) Counter Clockwise
3) Partial On High Dose Volume

Total of 732 MU and 483 control points with RapidArc vs. 1260 MU and 2020 control points for 9 field IMRT with carriage splits. More efficient use of MU’s and MLC’s to deliver the same dose.
Is it complicated to design the constraints?

Start simple to understand the behavior then refine.
Is it complicated to design the constraints?

Minimal Optimization

If you just push on the constraints to have a conformal dose distribution, how do the dose levels in the normal structures turn out?

✓ Cover IMRT PTV's
✓ Minimize High dose in DLA's
✓ Use NTO
Is it complicated to design the constraints?

Minimal Optimization

Original IMRT plan was designed with specific constraints for the normal tissues.

Simple approach to VMAT produced lower dose in

- L Parotid
- Phar Constrictors

Higher dose in

- Cord
- R Parotid

We can do better with more and specific constraints, but this simplistic approach takes us well along the way to a desirable plan.
Is it complicated to design the constraints?
Try IMRT constraints on a first pass at a VMAT plan

Should we consider a VMAT plan instead of the current IMRT plan?
As a first pass, try re-optimizing with the same constraint set and the set of 3 VMAT beams.
Setting the Normal Tissue Objective (NTO)

If you are not sure what parameters to use
- Optimize without the NTO
- Use the dose profile tool discover what fall off is reasonable
- Set NTO parameters to push it reasonably

- If the NTO is over constrained (i.e. physically unreasonable dose distribution) the results can be poor.
Since IMRT PTV has been contoured to reflect reasonable expectation of high dose (avoid buildup near skin, avoid overlap of normal tissues to be spared, differing dose levels, etc) set constraints to cover IMRT PTV.
Leverage ability, to hold RapidArc optimization at an early level (e.g. 2), to take your time to look at specific structure constraints one by one and avoid a cluttered screen.
Optimization Constraints
Parotid

Drive mean parotid dose low, by pushing on the low dose portion of the DVH curve.
Optimization Constraints
Spinal Cord

Set max on cord, then drive volume of cord buffer structure at that dose level to a lower volume.
Optimization Constraints
All Together
Comparison of IMRT and RapidArc

How quickly to planners climb the learning curve?

Clinical examples of cases where planners decided that they preferred the VMAT dose distribution.
Needed to reduce dose to contralateral parotids and submandibular glands.

L Parotid Mean

IMRT: 28.3 GY
RA: 22.8 GY
Needed to keep cord dose as low as possible.

**Cord Max**

- **IMRT:** 25.3 Gy
- **RA:** 22.5 Gy

**Cord PRV mean**

- **IMRT:** 18.9 Gy
- **RA:** 16.0 Gy

As bonus, oral cavity

- **IMRT:** 28.3 GY
- **RA:** 22.8 GY

Thanks to Kevin Kisrow
RapidArc gave very conformal dose distribution with significant reduction in dose to contralateral parotid and pharyngeal constrictors.
IMRT did better on reducing max larynx dose. For overall larynx dose distribution, RapidArc is lower.
Significant gains with RapidArc for:
- L Parotid
- Constrictors
- Cord

IMRT better for:
- Esophagus
- Larynx max
Couch Top

For CT couch tops attenuation is on the order of 4%. Including the couch top in the plan, to have this attenuation automatically factored into the plan, is optimal.
On the learning curve

Remember a lesson learned during IMRT about perceptions of new technology

\[ p(E) = p(E|Q) \cdot p(Q) \]

Given that the technology is capable, probability that the planner gets a better Rapid Arc Plan

Probability that VMAT technology is capable of a better plan

Not getting the plan we want could be \( p(Q) \) but it could also be \( p(E|Q) \).

Avoid temptation to judge a new technology, before staff have time to master it.
VMAT is emerging as a main stream treatment planning/delivery option

- Supported by multiple vendors
- Expanding number of facilities making use of the technology

VMAT does not have to mean compromise in sparing of normal tissues

VMAT planning can build upon IMRT planning approaches to facilitate transition, however additional “tricks” may be needed to get the most out of it.

There is a learning curve for getting good VMAT plans. Once there it becomes the preferred approach.