A Comparison of 3 VMAT Planning Approaches for Various Target Geometries in Spinal SBRT

Disclosure

• I have no affiliation to any company or any of their products showcased in this presentation, and have not received any compensation for doing so.
Learning Objectives

1. Comparing CMD (US) with CDC (CAN)
2. Summarize how spinal SBRT has come into practice
3. Identify 2 factors to assess plan quality
4. Identify 3 factors to assess plan efficiency
5. Demonstrate how spine volume shape impacts plan design

Queen Elizabeth Hospital

- Provincial referral center for specialized hospital services
- Charlottetown (~36,000) is the capital city of PEI
- PEI population ~153,000
Health PEI

One Island Health System

Prince Edward Island...
PEICTC Radiation Oncology

- Rad Oncs (2.5)
- Physicists (5)
- RTTs (14.5)
  - (includes 3 CMDs)
- GE CT Sim (1)
- Varian Linacs (3):
  - TrueBeam & iX
  - EX (not in use)

True Beam
Fall 2018  1st clinical patient

- First SRT Brain case in March 2019
Outline

- Learning Objectives
- Compare Certified Medical Dosimetrist (CMD) VS Canadian Dosimetry Certificate (CDC)
- Research presentation
  - Spine radiotherapy review
  - Materials & Methods
  - Results
  - Conclusions
  - References

Certified Medical Dosimetrist (CMD) VS Canadian Dosimetry Certificate (CDC)
### CDC CMD

**Purpose**

- Provides a mechanism for radiation therapists to demonstrate knowledge and competence in the field of dosimetry, promotes standards of excellence and to identify those who have met a nationally recognized standard in the practice of medical dosimetry.

- Offered by the MDCB to represent a recognized standard of knowledge and education. Certification is intended to define the field of medical dosimetry and to protect and promote the safety and health of individuals requiring the services of a medical dosimetrist.

**Eligibility Criteria**

- Full Practice Member of CAMRT
- Non-member certified by the CAMRT
- Successful completions of CAMRTs Dosimetry 1 course with a minimum mark of 75% on the final examination.
- Two years’ work experience post-certification as a radiation therapist.
- Practicing within Dosimetry in order to complete the Summary of Clinical Competence.
- Canadian candidates are considered international applicants and must:
  1. Hold a Bachelor of Science degree in Radiation Therapy, Radiation Science or Radiography
  2. Have achieved a minimum grade of C or 70-79% in Anatomy and/or Physiology, Brachytherapy, Clinical Anatomy, Radiation Oncology, Radiation Physics, Radiobiology and Treatment Planning.
  3. Have completed 1,000 clinical curriculum hours in treatment planning during Bachelor of Science degree course of study.

**Assessment**

- Candidates must successfully complete the 2 remaining full-length courses Dosimetry 2 & 3 with a minimum examination mark of 75%, complete a Summary of Clinical Competence and a research project.
- The CDC credential is granted upon completion.
- Applicants who meet the MDCB eligibility criteria are able to apply for the exam.
- Those who pass the board exam are granted the CMD designation.

### CDC CMD

**Continuing Professional Development**

- Annual CPD is strongly recommended.
- Annual CPD is required for continued use of designation.

**Initial Fees**

- $350 CAD* per course ($1,050 CAD total)
- $375 CAD* Certificate program registration fee
- Total CDS cost = $1,425 CAD* ($998 USD)

*Based on the CAMRT member rate

**Maintenance Fees**

- There is no renewal or maintenance fee.
- Cost for 10 years = n/a

**Pros**

- Comprehensive program providing didactic, clinical, research and CPD components
- - Canadian program developed by the CAMRT

**Cons**

- Can take 2 to 5 years
- More expensive initially
- Requires better recognition nationally and internationally

**Total CMD cost = $575 USD**

- Quicker to obtain (but requires three years dosimetry experience and 24 MDCB approved CE credits)
- More widely recognized

**Does not provide education**

- Not Canadian (coming from CAMRT publication)
- More expensive to maintain

### Health PEI

**One Island Health System**

---

**Table:**

<table>
<thead>
<tr>
<th>CDC</th>
<th>CMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Provided mechanism for radiation therapists to demonstrate knowledge and competence in the field of dosimetry, promotes standards of excellence and to identify those who have met a nationally recognized standard in the practice of medical dosimetry. Offered by the MDCB to represent a recognized standard of knowledge and education. Certification is intended to define the field of medical dosimetry and to protect and promote the safety and health of individuals requiring the services of a medical dosimetrist.</td>
</tr>
<tr>
<td><strong>Eligibility Criteria</strong></td>
<td><strong>Eligibility Criteria</strong></td>
</tr>
<tr>
<td>Full Practice Member of CAMRT</td>
<td>Full Practice Member of CAMRT</td>
</tr>
<tr>
<td>Non-member certified by the CAMRT</td>
<td>Non-member certified by the MDCB</td>
</tr>
<tr>
<td>Successful completions of CAMRTs Dosimetry 1 course with a minimum mark of 75% on the final examination.</td>
<td>Successful completions of CAMRTs Dosimetry 1 course with a minimum mark of 75% on the final examination.</td>
</tr>
<tr>
<td>Two years’ work experience post-certification as a radiation therapist.</td>
<td>Two years’ work experience post-certification as a radiation therapist.</td>
</tr>
<tr>
<td>Practicing within Dosimetry in order to complete the Summary of Clinical Competence.</td>
<td>Practicing within Dosimetry in order to complete the Summary of Clinical Competence.</td>
</tr>
<tr>
<td>Canadian candidates are considered international applicants and must:</td>
<td>Canadian candidates are considered international applicants and must:</td>
</tr>
<tr>
<td>1. Hold a Bachelor of Science degree in Radiation Therapy, Radiation Science or Radiography</td>
<td>1. Hold a Bachelor of Science degree in Radiation Therapy, Radiation Science or Radiography</td>
</tr>
<tr>
<td>2. Have achieved a minimum grade of C or 70-79% in Anatomy and/or Physiology, Brachytherapy, Clinical Anatomy, Radiation Oncology, Radiation Physics, Radiobiology and Treatment Planning.</td>
<td>2. Have achieved a minimum grade of C or 70-79% in Anatomy and/or Physiology, Brachytherapy, Clinical Anatomy, Radiation Oncology, Radiation Physics, Radiobiology and Treatment Planning.</td>
</tr>
<tr>
<td>3. Have completed 1,000 clinical curriculum hours in treatment planning during Bachelor of Science degree course of study.</td>
<td>3. Have completed 1,000 clinical curriculum hours in treatment planning during Bachelor of Science degree course of study.</td>
</tr>
<tr>
<td><strong>Assessment</strong></td>
<td><strong>Assessment</strong></td>
</tr>
<tr>
<td>Candidates must successfully complete the 2 remaining full-length courses Dosimetry 2 &amp; 3 with a minimum examination mark of 75%, complete a Summary of Clinical Competence and a research project.</td>
<td>Candidates must successfully complete the 2 remaining full-length courses Dosimetry 2 &amp; 3 with a minimum examination mark of 75%, complete a Summary of Clinical Competence and a research project.</td>
</tr>
<tr>
<td>The CDC credential is granted upon completion.</td>
<td>The CDC credential is granted upon completion.</td>
</tr>
<tr>
<td>Applicants who meet the MDCB eligibility criteria are able to apply for the exam.</td>
<td>Applicants who meet the MDCB eligibility criteria are able to apply for the exam.</td>
</tr>
<tr>
<td>Those who pass the board exam are granted the CMD designation.</td>
<td>Those who pass the board exam are granted the CMD designation.</td>
</tr>
</tbody>
</table>

---

**Initial Fees**

- **CDC**
  - $350 CAD* per course ($1,050 CAD total)
  - $375 CAD* Certificate program registration fee
  - Total CDS cost = $1,425 CAD* ($998 USD)

*Based on the CAMRT member rate

- **CMD**
  - $200 USD application fee and $375 USD exam fee
  - Total CMD cost = $575 USD

**Maintenance Fees**

- **CDC**
  - There is no renewal or maintenance fee.
  - Cost for 10 years = n/a

- **CMD**
  - Renewal fees per annum = $175 USD
  - Cost for 10 years = $1,750 USD

**Pros**

- Comprehensive program providing didactic, clinical, research and CPD components
- Canadian program developed by the CAMRT

**Cons**

- Can take 2 to 5 years
- More expensive initially
- Requires better recognition nationally and internationally

- Does not provide education
- Not Canadian (coming from CAMRT publication)
- More expensive to maintain
CDC Components

• Clinical
  ‣ 130 competencies: varied sites, techniques, scenarios etc
  ‣ All reviewed by an MCCPM certified physicist

• Didactic
  ‣ Complete 3 Dosimetry courses offered by CAMRT (>75% pass)

• Research
  ‣ Submit an original research paper

Research

A Comparison of 3 VMAT Planning Approaches for Various Target Geometries in Spinal SBRT
CDC Research Project

- A research project is mandatory as part of the CDC certification process
- I undertook a comparison of 3 volumetric modulated arc therapy (VMAT) plan designs to determine which plan maximally spared the spinal cord while maintaining delivery efficiency & target coverage

Background for palliative spinal RT

- The primary purpose of spinal RT in the palliative setting is pain relief, inhibiting tumor growth, and avoiding surgery
- Traditionally RT for spine metastasis has had limited success
  - Only 50% of patients report complete pain relief
- Many patients present with limited disease spread (1-5 radiographic sites) which affords an opportunity to treat such patients more aggressively than traditional spine RT
- Such oligometastatic disease leaves a potential for longer survival and improved quality of life if treated with a higher and more conformal dose (i.e. spinal SBRT)
Background for palliative spinal RT

- Dose escalation has been traditionally limited by the dose tolerance of the spinal cord

- With the advent of new technologies (IGRT, IMRT, SBRT) dose escalation is feasible

- SBRT for spinal metastases has been shown to be superior to standard RT approaches in achieving pain control rates of up to 80% (VS 50%) after a one year follow up
Background for palliative spinal RT

- Much of the research in dosimetry has compared static field IMRT vs VMAT
- Both IMRT and VMAT produce high quality, conformal isodose distributions

**BUT**

- VMAT is superior to IMRT in its’ expedient treatment delivery which is important in the ablative radiotherapy setting

Comparison of different beam arrangements...
Study Rationale

- Many studies have compared IMRT to VMAT for delivery of spine RT
- Only a few studies have investigated the optimization of VMAT plans with various arc arrangements for the treatment of spinal RT
- An analysis of the optimal number of arcs and beam arrangement is of clinical significance especially for spine SBRT treatments
- In general, more complex shapes should require more arcs to deliver equivalent quality plans
- As an end point for assessing plan quality, spinal SBRT plans must meet RTOG dosimetric criteria while also maintaining efficiency in plan delivery

Study Design

- 3 Target shapes:
  - A
  - B
  - C

- 3 Plan designs:
  - 1 Full Arc
  - 2 Full Arcs
  - 2 Partial Arcs
Study Design

• Each of the 9 total plans:
  ‣ used an image data set from the Visible Human Project
  ‣ was performed by the same dosimetrist
  ‣ used the same planning objectives for optimization

• While other studies have used similar study designs this study is limited by
  ‣ patient sample size
  ‣ one dosimetrist

• The research was intended to be a pilot project to prompt further investigation

Health PEI

One Island Health System
Contouring: Spinal Cord

- Image fusion with T1 & T2 weighted MR with CT

- 1.0 mm CT slice thickness
  - Contours drawn on every slice

- Defined two 'Cord' structures for planning (RTOG 0631)
  - Spinal Cord
    - 10 cm SUP and INF above and below target
  - Partial Cord
    - 5-6 mm SUP and INF above and below target

- OARs (RTOG 0631)
  - Skin, esophagus, lungs, great vessels

Spinal Cord & Partial Spinal Cord (RTOG 0631)
Contouring: Radiosurgery volumes

- Three typical case presentations of spine metastases
- Target volumes were contoured at the same anatomical location in the same image data set to control for any variability that could impact dosimetry
- Margin = 0 mm
  - RTOG 0361 used 0 mm
  - Clinical margins can range from 0-3 mm depending on clinical case and delivery system (e.g. linac precision: TrueBeam micro MLC VS iX standard MLC)

Most common presenting metastatic spinal lesions (RTOG 0631)

- **Black**
  - represents visible tumor
- **Red**
  - shows typical target volume delineation
Technical Parameters:

- For all 3 plan types (1 and 2 full arc, 2 partial arc):
  - Field sizes
    - encompass the individual targets
  - Collimator rotations of 30° & 330°
    - used to minimize tongue and groove effect

- The 2 Partial arcs plan
  - used avoidance sectors: CW:270.0°-90.0°, CCW:90.0°-270.0°
    - optimally targets the spine from its POST location and avoids ANT located OARs

Prescription & Planning Objectives

- Plan normalization – 100%
- Eclipse treatment planning system
  - AAA v11.0.31
- Maximum dose rate = 600 MU/min
- MLC leaf width = 5.0 mm
- Heterogeneity = ON
- Calc. grid size = 1.0 mm
- NTO was the same for all plans
  - Note: dose fall off may be more influenced by optimization ring structures than the NTO itself
Plan objectives...

- Plans were optimized with the goals of meeting dose constraints from RTOG 0631
- Planned with 6MV photons
- Dose/Fractionation
  - 18 Gy /1#
- Target constraint to determine plan completion:
  - at least 90% of the target volume received 100% of the prescribed dose

OAR Constraints

- Three spine OAR constraints needed to be met:
  - Partial Spinal Cord
    - < 10 Gy to ≤ 10% of the volume
  - Spinal Cord
    - < 0.35cc < 10 Gy
    - Maxdose < 14 Gy to ≤ 0.03cc
- Any spinal dose that exceeded these OAR constraints was deemed not acceptable
Plan Objective Template...

<table>
<thead>
<tr>
<th>Structures and Objectives</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>BODY</td>
<td>150</td>
</tr>
<tr>
<td>body sub A</td>
<td></td>
</tr>
<tr>
<td>OARs</td>
<td></td>
</tr>
<tr>
<td>Esophagus</td>
<td></td>
</tr>
<tr>
<td>GTV A</td>
<td></td>
</tr>
<tr>
<td>LUNGS</td>
<td></td>
</tr>
<tr>
<td>partial cord</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volume (cc)</th>
<th>Points</th>
<th>Dose (cGy)</th>
<th>Resolution (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BODY</td>
<td>21415</td>
<td>21850</td>
<td>4.50</td>
</tr>
<tr>
<td>body sub A</td>
<td>21207</td>
<td>209648</td>
<td>2.65</td>
</tr>
<tr>
<td>OARs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esophagus</td>
<td>20</td>
<td>4247</td>
<td>1.01</td>
</tr>
<tr>
<td>GTV A</td>
<td>540</td>
<td>1900</td>
<td>1.31</td>
</tr>
<tr>
<td>LUNGS</td>
<td>5550</td>
<td>54819</td>
<td>4.50</td>
</tr>
</tbody>
</table>

Health PEI
One Island Health System
Outline of Results

- DVHs of target coverage & OARs
- Bar Graphs
  - Target coverage:
    - D90 ≥ 18Gy
    - Dmin
  - Cord metrics:
    - D10% (≤10Gy) to partial cord
    - D0.35 cc (≤10Gy) to cord
    - D0.03 (<14Gy) to cord
  - Plan Quality Indices:
    - Fall Off
    - Conformity Index
  - Plan Efficiency:
    - MUs
    - Delivery Time
    - Modulation Factor

**DVH Target A**

Figure 5. Dose volume histogram plan comparison for 1 full arc, 2 full arcs and 2 partial arcs for coverage of target A, and dose to conventional spinal cord and partial spinal cord.
Figure 6. Dose volume histogram plan comparison for 1 full arc, 2 full arcs and 2 partial arcs for coverage of target B, and dose to conventional spinal cord and partial spinal cord.

Figure 7. Dose volume histogram plan comparison for 1 full arc, 2 full arcs and 2 partial arcs for coverage of target C, and dose to conventional spinal cord and partial spinal cord.
D90 ≥ 18Gy (RTOG constraint) \[ D_{\text{min}} > 90\% \]

- 1 and 2 arc techniques meet D90 ≥ 18Gy (RTOG)
  - Again, shows 2 partial arc not viable
- 1 and 2 arc techniques meet $D_{\text{min}} > 90\%$ for Targets A and C
  - None of the techniques meet $D_{\text{min}} > 90\%$ for Target B
  - suggests more complicated technique may be necessary for this complex shape

**Summary: Target Coverage**

- Compared to the 1 and 2 full arc options the 2 partial arc planning technique is the least viable for all 3 target shapes
  - has the worst target coverage
  - has the highest cord doses
- The 1 and 2 arc techniques meet
  - $D90 \geq 18Gy$ (RTOG) – all target shapes
  - $D_{\text{min}} > 90\%$ - targets A and C only
- Target shape B is too complex to meet $D_{\text{min}} > 90\%$ for all of the techniques
Summary: OAR sparing

- The 1 arc and 2 full arc plans met all cord objectives required from the RTOG
  - Conventional Cord
    - D0.035cc ≤ 10 Gy
    - D0.03cc ≤ 14 Gy
  - Partial Cord
    - D10% ≤ 10 Gy

- All other OARs met RTOG objectives
  - i.e. esophagus, lungs, skin and great vessel
Plan Quality

- Dose Fall Off = The maximum dose @ 2 cm away from the target
- Only 1 and 2 arc plan techniques met the dose fall off criteria of < 50% which is standard for SBRT

Conformity Index (CI) = Volume of 100% isodose line and Target Volume
- CI for 1 and 2 arc plan techniques are within an acceptable range for Target A and B
- CI for Target C is not ideal for any of the 3 plan techniques

Delivery Efficiency

- 2 partial arc technique had lowest MUs, delivery time, and modulation
  - BUT does not meet dosimetric endpoints (as already shown)
- 1 arc plan performed better than 2 arc plan for MUs, delivery time, and modulation

One Island Health System
### Summary: Plan Quality and Delivery Efficiency

- **Dose Fall Off**
  - 1 & 2 arc plans had acceptable fall off
  - 2 partial arcs plans did not
- **Conformity Index**
  - 1 & 2 arc plans CI was acceptable for Targets A & B
  - CI for all plan types was poor for Target C
- **Delivery Efficiency**
  - 1 arc plan was optimal for MUs, delivery time, and modulation
    - recognizing 2 partial arc plan is not dosimetrically viable

### Summary of Results

<table>
<thead>
<tr>
<th></th>
<th>Target Coverage</th>
<th>OAR Sparing</th>
<th>Plan Quality</th>
<th>Delivery Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 arc</td>
<td><img src="image" alt="Smiley" /></td>
<td><img src="image" alt="Smiley" /></td>
<td><img src="image" alt="Smiley" /></td>
<td><img src="image" alt="Smiley" /></td>
</tr>
<tr>
<td>2 arc</td>
<td><img src="image" alt="Smiley" /></td>
<td><img src="image" alt="Smiley" /></td>
<td><img src="image" alt="Smiley" /></td>
<td><img src="image" alt="Smiley" /></td>
</tr>
<tr>
<td>2 partial arc</td>
<td><img src="image" alt="Smiley" /></td>
<td><img src="image" alt="Smiley" /></td>
<td><img src="image" alt="Smiley" /></td>
<td><img src="image" alt="Smiley" /></td>
</tr>
</tbody>
</table>
Study Limitations

- Single Planner Study
  - Intra-planner variability

- Optimization Criteria

- Anatomical Location
  - Single thoracic vertebrae location was used
  - Change in location SUP/INF may alter dosimetry (OARs etc.)

- Use of evaluation metric other than RTOG

Small sample size

Margins = 0 mm
  - May not be achievable clinically
  - Adding a margin 0 – 3 mm may alter results

- Technological Limitations
  - Conclusions may change with use of:
    - FFF
    - uMLC
    - Treatment Planning Algorithm
Summary

- Metastases to the spine are the most common site for cancer to spread.
- RT is an oft sought option in treatment for metastatic tumors of the spine.
- The primary limiting factor for dose escalation is the spinal cord.
- Technological advances (IGRT, VMAT) facilitate tumor targeting and helps to avoid overdosing sensitive structures such as the spinal cord.
- This has allowed dose escalation to the target while minimizing the risk of complications such as paralysis.
- Using spinal SBRT local control rates of 92% for neurological complications and radiological abnormalities have been achieved.
- Knowing the best planning technique to achieve this aim will improve outcomes.

1 Arc Plans
Showing targets A, B, & C
Conclusions

• Overall, the 1 arc plan was found to be superior among the 3 treatment plans investigated for all three targets

• “Sometimes the simplest approach is the best approach”

Acknowledgements

• I would like to thank the support of many colleagues from the Radiation Oncology department at the Prince Edward Island Cancer Treatment Center

• Many thanks to all of you for your attendance and support!
Contact Information:

- Ms. Leah CLASSEN, BSc., RT(T), CMD, CDC
- Prince Edward Island Cancer Treatment Centre
  - Dosimetrist/Radiation Therapist
  - 60 Riverside Drive
  - Charlottetown, PE
  - C1A 8T5
  - ljclassen@ihis.org
  - (902)-894-2963

Questions
References
