RapidArc for SRT

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RapidArc for SBRT: Overview

• SRT for multiple brain metastases
  – Rationale for WBRT + simultaneous integrated boost
  – RapidArc optimization, dose measurement and delivery

• SBRT in lung
  – Rationale for faster delivery; dose prescription
  – RapidArc plan optimization
    • Problems of different dose engines
    • Constraint sets, including contralateral lung doses
  – Dosimetry
    • Measurements compared with calculations
    • Interplay effect between moving leaves and moving target
Out-field metastases after SRT in patients presenting with 1-3 metastases [VUMC, unpublished]

VUmc

Why add WBRT for 3 brain metastases?

Outfield-failure free survival

Single lesion: N=156 (63%)
Two lesions: N= 69 (28%)
Three lesions: N= 21 (9%)

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Approaches for combining WBRT and SRT

Conventional RS

WBRT dose distribution corrected for contribution from boost doses

RapidArc WBRT with SIB

VUmc
**Chang EL, 2009**: Patients treated with SRT plus WBRT in a randomized trial were at greater risk of significant decline in learning and memory function by 4 months compared with the group receiving SRT alone.

**Lagerwaard F, 2009**

- Rapid dose fall-off around SIB
- Homogeneous whole brain dose (avoid hot spots)
- WBRT = 5x4 Gy
- Sim. Integrated Boost = 5x8 Gy
RapidArc: routine use of 2 arc delivery
(Lagerwaard F, 2009)

1\textsuperscript{st} arc 2\textsuperscript{nd} compensatory arc Dose summation

2 arcs delivery results in a more homogeneous dose distribution
RA delivery times < 3 minutes
RapidArc optimization

Constraints on
- WBRT-ring-boost
- Boost PTVs
- Ring around boost
- Ring around WBRT
- Eye lens < 7 Gy
- WBRT-ring-boost $V_{22\text{Gy}} < 10\%$
- Boost dose 38 - 45 Gy (95%-114%)
WBRT + SIB for brain mets

RapidArc vs conventional sequential boost

Dose >115% (23 Gy)
Benefits of using RapidArc for SIB

Improves dose gradients outside the metastases

• Conventional treatment times *
  • WBRT 5x10=50 minutes
  • SRS (3 metastases) 90 minutes
  • TOTAL TIME 140 minutes
• RapidArc treatment times
  • WBRT + Integrated boost 5x15=75 minutes

* All times including online image guided setup
Use of 2 arcs = better agreement between measurements and calculations (Verbakel, 2009; Lagerwaard, 2009)

- AAA does not accurately calculate dose modulation
- 2nd arc compensates for modulation of the first arc

Gafchromic EBT-I film, Gamma 3% - 2 mm

<table>
<thead>
<tr>
<th>No. of pixels exceeding gamma criteria</th>
<th>&lt;1%</th>
<th>1-2%</th>
<th>2-5%</th>
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<tr>
<td>Number of patients</td>
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<td>5</td>
<td>4</td>
<td>0</td>
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</table>

Total gamma > 1 1.6%
Average gamma 0.34
Preliminary analysis in 40 patients (Lagerwaard F, unpublished)

Should preferably be restricted to patients with a good performance score (PS)

Number of metastases (3-5) and their volume (<20-25cc) appears to be less important than PS
Conventional SBRT for lung

Very low toxicity [Lagerwaard F, 2008]
- Pneumonitis = 3.5%, rib fractures = 2%, chest pain = 5%

Disadvantage of 8-12 static non-coplanar beams
- Delivery times (minus setup) of 10 – 16 min
- > 25% require repositioning during treatment
- Limited conformality for larger and irregular tumors

Speed has great impact in stereotactic RT!
- Improved patient comfort
- Stability of patient set-up and tumor position
- Utilization of personnel & equipment
- Potential radiobiological effects of longer treatments
• 200 patients treated since Sept 2008

• Three ‘risk-adapted’ fractionation schemes
  • 3 x 18 Gy or 5 x 11 Gy or 8 x 7.5 Gy at 80% (95% of PTV)
  • PTV = ITV encompassing all motion + 5 mm margin
  • Dose prescription, OAR doses \([\text{ROSEL study, Hurkmans 2009}]\)
  • \(D_{\text{max}}\) in PTV up to 140% of prescription

• CBCT based setup on PTV

Verbakel W, 2009
RA versus conv. SBRT: planning study

- 15 RapidArc cases replanned using 10 static non-coplanar beams
- CI_{80} and CI_{60} superior for RapidArc plans
- Chest wall receiving $\geq$45 Gy lower for RapidArc plans
- Current constraint for contralateral lung (V5 <25%)
- Delivery time (1000 MU/min): 3 min (7.5 Gy) – 6.5 min(18 Gy)

Conv. SBRT delivery times averaged 11.6 minutes

Verbakel, W Proc. ASTRO 2009
- Differences between dose calculation algorithms in optimization (Multi Resolution Dose Calculator) and AAA: PTV dose appears more homogeneous in the optimizer than in AAA.

**DVH optimizer (end optimization)**

**Same plan (AAA)**
Sequential RA optimization - 2 arcs

- Typical plan > 2000 MU; extra imaging between arcs
- 2\textsuperscript{nd} arc uses plan for first arc as ‘Base Dose Plan’

1\textsuperscript{st} arc (more inhomogeneous dose) 2\textsuperscript{nd} arc
Typical optimization constraints

- **PTV** consisting of $PTV_{OAR} + PTV_{lung}$
- $\leq 140\%$ of dose accepted in $PTV_{lung}$ and $ITV_{lung}$
- **Contralateral lung**: low V5
- **Ring for dose fall off** (green line)
- **Ribs doses** >V40Gy minimized
Limit contralateral lung V5 [Ong C, ASTRO 2010]

- Use of partial arcs or avoidance sector
- Our *preference* is for an *avoidance sector*
RapidArc applied in large tumors
PTV > 200 cc: use of 2 partial arcs
PTV > 200 cc: use of 2 partial arcs
Example: Reducing chest wall dose

- Plan for 8x7.5 Gy
- Thorax dose: V40Gy and V60-65Gy (inside PTV)
- Initial plan: V40Gy = 9%
- Narrow optimization window for PTV in OAR
• New plan: V40Gy = 5.5%
• Allows ≤64 Gy in PTV in OAR instead ≤62 Gy
• Allow slightly higher V5 in CL-lung
• **Background:** Interplay between moving leaves and moving target can be important with Tomotherapy and conventional doses delivered using RapidArc

• Static measurements convoluted with motion, and compared with moving film

• **Gamma (3%, 1 mm) > 1:** 3-5%

• **No interplay effects observed for RapidArc SBRT plans**
  • *Measured in 11 patients with motion amplitude > 5 mm*
  • *For plans with excessive MU and 25 mm amplitude [Fig below]*
No reasons to indicate concerns about toxicity or efficacy

**CLINICAL INVESTIGATION**

**RADIOLOGICAL AND CLINICAL PNEUMONITIS AFTER STEREOTACTIC LUNG RADIOTHERAPY: A MATCHED ANALYSIS OF THREE-DIMENSIONAL CONFORMAL AND VOLUMETRIC-MODULATED ARC THERAPY TECHNIQUES**

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**Manuscript in press:** Lung density changes after stereotactic radiotherapy: A quantitative analysis in 50 patients. DA Palma, et al

**Manuscript under review:** Treatment of large stage I-II lung tumors using SBRT: planning considerations and early toxicity. Ong CL, et al
Conclusions

• Fast lung SBRT in <6.5 mins delivery time
  • Total linac time (+ CBCT set-up) 20 minutes
  • Superior OAR sparing possible
  • Less chance for intrafraction motion

• No interplay effect between moving tumor and moving leaves

• More time for appropriate and efficient IGRT