CyberKnife SBRT: High accuracy for high control of moving targets

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Contents

- How much do moving targets move?
- What do we need to hit them precisely?
- How does the precision translate into clinical benefit?
Moving targets in stereotactic radiotherapy
Key questions in moving targets

- How big and how predictable is their movement?
- How do we define the target volume?
- How do we track the target during the treatment?
How much do moving targets move?

- Organ
- Location within the organ
- Other variables
  - gender
  - tumor type

- If we don’t properly identify the movement, we can’t define the target precisely and we miss a part of it
- Risk of marginal recurrence
How can we analyze the movement of targets?

- Pretreatment analysis
  - 4DCT, cineMRI
    - insufficient predictive power for movement

- Interfractional analysis
  - daily IGRT
    - simple but insufficient

- Intrafractional analysis
  - online tracking
  - collection of data from log files
    - demanding but precise
Log files from online tracking

- Excellent source of data
- Analysis of movement – translation and rotation
- Variability among patients and among fractions in one patient
- Purpose: to find a predictive model for individualized target delineation
Pancreas

- 20 patients
- analysis of log files
- Periodical maximum and minimum tumor positions with respiration in superior-inferior (SI), latero-lateral (LL), and anterior-posterior (AP) directions were collected for tumor motion evaluation.
- The predictability of tumor motion in each axis, based on reference measurement, was analyzed.
Significantly more movement in SI and AP directions in women than in men

The more movement recorded in the reference measurement, the more variability during the treatment

Different variability in men and women in the SI and LL directions

Liver

- 20 patients with liver metastases

- Tumor motion amplitudes in the superior-inferior (SI), latero-lateral (LL), and anterior-posterior (AP) directions were collected

- The predictability of tumor motion in each axis based on the reference measurement and intra-/interfraction motions was analyzed.

- Analysis of 96,000 amplitudes
Liver
Liver

- Again: the more movement recorded in the reference measurement, the more variability during the treatment
- Much weaker dependence on gender

Lung

- Log file analysis from online respiratory tumor tracking in 145 patients (world’s largest group)
- Tumor motion variability during treatment was described using intrafraction/interfraction amplitude variability and tumor motion baseline changes
The closer to diaphragm, the more motion
The more motion, the more variability
Motion in the SI direction. Men/women, primary/mets.

Gradual motion of target center in the AP direction within 30 mins.
Lung

- The more movement, the more variability
- Gender is a strong factor
- Metastases and primaries move differently


Prostate
What do we need to hit the target?

- Current target definition methods are insufficient for moving targets (including 4DCT or cineMRI)
- The majority of patients still does well with those
- We need to define patients at risk for big variation in target movement
  - anatomic location
  - tumor origin
  - gender
  - others
- Online tracking!
Myths about online tracking

- very complex
- extremely time-consuming setup
- very slow treatment with plenty of interruptions
- inconvenient for patients
- doesn’t make a difference anyway…
Reality

- Minimizing the margins MUST be the goal in high precision radiotherapy
- Online tracking is the right way
- Now ALL manufacturers do recognize that
Real-time Tracking

Intracranial and extracranial tracking solutions from Varian provide continuous and real-time tracking to enable radiation oncology clinicians to keep the target in the path of the radiation beam at all times. By detecting the slightest tumor movement—and enabling the patient to be repositioned if necessary—Varian real-time tracking solutions help clinicians deliver maximum radiation directly to the tumor while avoiding healthy surrounding tissues and organs.
Our results
Prostate

- Over 1000 patients between 8/2010 and 10/2016
- 261 patients between 8/2010 – 8/2012
  - Low risk 80%
  - Intermediate risk 20%
- Median age 67 let (46 – 83)
- Median PSA 6.7 ng/ml (1.5 – 15)
- Median CTV 49 ml (18 – 68)
- CyberKnife SBRT 36.25 Gy/ 5 fractions / 10 days
PSA level in time
Late toxicity (RTOG)

**chron. tox. Urol (%)**
- 0: 81.28%
- 1: 18.18%
- 3: 0.53%

**chron. tox. GIT (%)**
- 0: 96.83%
- 1: 2.12%
- 2: 1.06%
EPIC – urogenital
EPIC – gastrointestinal
Lung

- 97 patients with early inoperable NSCLC (medically or refused)
- 67 males, 30 females
- Median age 70 years (range 50 – 92)
- T1-2N0M0 (48 patients with T1 and 49 with T2 lesions)
- Histologically or cytologically confirmed
- Median follow-up 24 months
The treatment

- CyberKnife
- 60 Gy/3 fractions for peripheral lesions
- 60 Gy/5 fractions for central tumors
- Online tracking with respiratory synchronization, 83 per cent of cases
- Spine tracking (ITV) 17 per cent of patients
- Median GTV 17 cm³ (range 1,5 – 164)
Overall survival. Females, males.
Overall survival, T1 vs. T2.
Females vs. males T1

Comparison of Survival Curves

Log-rank test

Chi square 3,708
df 1
P value 0.0442
P value summary s

Are the survival curves sig different? Yes

Hazard Ratio
Ratio 4,944
95% CI of ratio 0.9803 to 9.366
Females vs. males T2

Comparison of Survival Curves

Log-rank test
Chi square: 1,357
df: 1
P value: 0.2441
P value summary: ns
Are the survival curves sig different? No

Hazard Ratio
Ratio: 1.786
95% CI of ratio: 0.6925 to 4.236
Liver and pancreas

- Palliative intent
- Negligible toxicity, high comfort
- Fiducials necessary

- Liver: oligometastases (up to three)
- Pancreas: locally advanced, inoperable, nonmetastatic
Overall survival - liver
Overall survival - pancreas

Median survival - 13 months

Percent survival

Time / months
Conclusion

- Moving targets are a big challenge in high precision radiotherapy
- Our data show that some moving targets might have insufficient margins (too big or too tight)
- Robust predictive models are needed for appropriate PTV delineation (locations with very high variability of movement)
- Online tracking is currently the best solution
Thanks for listening!