Extracranial Stereotactic Radiosurgery

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Stereotactic Radiosurgery

Using stereotactic techniques, give a lethal dose of ionizing radiation to the target, while minimizing the toxic radiation to the surrounding tissue = High doses of radiation to defined target volumes

Basic technique

• Multiple radiation beams converge on the lesion
• At the intersection a high dose is delivered, while the surrounding tissue receives a minimal dose

Linear accelerators

• Various systems:
  – X-knife®
  – Novalis®
  – Cyberknife®
  – Trilogy®
  – Synergy®

Linear accelerator-based SRS

• Frame based:
  – X-knife
  – Novalis

• Frameless:
  – Cyberknife
  – Trilogy
  – Synergy

Indications of SRS

• Cells with neoplastic growth (benign and malignant)
• Vascular malformation
• Lesionectomy: Functional Neurosurgery (trigeminal neuralgia)
Cyberknife® Radiosurgery

Historical notes
- Accuray founded in 1992
- First patient treated in 1994
- CyberKnife System FDA Clearance – August 2001

“To provide treatment planning and image-guided radiosurgery and precision radiotherapy for lesions, tumors, and conditions anywhere in the body when radiation treatment is indicated.”

CyberKnife System
- The CyberKnife® is a lightweight linear accelerator mounted on a robotic arm.
- Does not rely on a fixed, invasive frame to keep the target organ immobile, thus can be used throughout the body.
- Two ceiling mounted cameras perform near real-time image tracking with 1 mm spatial accuracy.
- The robot relates the identified lesion to radiographic landmarks (the patient’s skull).

Advantage of the Cyberknife
- “Frameless” technique does not affect accuracy but allows for extracranial targeting
- Ability to fractionate treatment allows treatment of lesions abutting or involving radio-sensitive structures like the optic apparatus

CyberKnife
- 6 MeV linac mounted on robot arm- 6 degrees of rotation
- 100 treatment positions (nodes) with the possibility to use 1, 200 intersecting beams of radiation
- 2 cross-firing X-ray cameras monitor patient position
- Robot corrects for patient motion
CyberKnife

• Continuously monitors and corrects for changes in patient position and motion by comparing pretreatment CT-based digitally reconstructed radiographs (DRR’s) to digital radiographs acquired throughout the radiosurgical treatment.
• Adjusts the position of the robotically targeted accelerator accordingly

CyberKnife Treatment (cont.)

• Radiosurgery in early days was only performed with single high doses of radiation.
• In contrast benefit of fractionation is well established in general radiotherapy
• CyberKnife’s capability to treat without head ring and to treat extracranial lesions has created a pathway for fractionation

Process

• Once the fiducials have been implanted the treatment process consists of three basic steps
  • 1) Treatment set-up,
  • 2) Treatment planning,
  • 3) Treatment delivery

Treatment Set-up

• Technology can compensate for minimal movements, larger patient movements are limited by fitting the patient with an immobilization device. A custom-fit, flexible mesh mask (for head/neck treatments) or body cradle is formed and is used to help minimize movement during the treatment and ensures patient comfort

Immobilization for intracranial (or head & neck) lesions

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Immobilization for extracranial lesions

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What is a fiducial?

• Frameless radiosurgery allows ablation of tumors anywhere within the body
• For intracranial lesions a comparison between bony profiles from DRRs and x-ray images is employed to position patient.
• Match the bony skull based landmarks from CT-based DRRs to those captured by the orthogonal pair of digital X-ray images
• Patient repositioned until perfect match is made.

Fiducials (cont.)

• For targets outside the skull there is a need to define an intermediate spatial reference system that is visible in CT and in conventional X-ray.
• For this purpose before CT scanning 3-6 gold fiducials are inserted in or around the tumor

Fiducial Placement

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Image acquisition

Image not available

Treatment Planning

• Inverse treatment planning: Clinician specifies the total dose to be delivered to the tumor and sets boundaries to protect the critical structures. The software then determines the targeting positions and dose to be delivered from a particular targeting position.

Treatment Delivery

• Occurs 1-5 days after planning
• Patient fitted with immobilization device
• Imaging system acquires digital x-rays of the patient position.
• Information is used to move the linear accelerator to the appropriate position
• Robot moves and re-targets the linear accelerator at a large number of positions around the patient. At each position or “node”, a small radiation beam is delivered.
Treatment Delivery (cont)

• This process is repeated at 50 to 300 different positions around the patient to complete the treatment.
• The entire process is painless and typically takes between 30 to 120 minutes to deliver all radiation beams depending on tumor location.
• Most typically a patient can go home immediately upon completion and return to normal activities.

The Cyberknife “Team”

• Radiation Oncologist
• Neurosurgeon/surgeon
• Physicist
• Medical Oncologist
• Nurse
• Radiation Therapist

Treatment Planning System

Image not available

Alignment Screen

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Unlimited Potential

• Instrument expands far beyond current 1,200 beams (targeting positions and approach angles)
• System utilizes CT and MRI scans for treatment planning
CyberKnife Clinical Indications

- Lesions adjacent to radiosensitive structures
- Minimal or neurological deficit
- Complex-shaped lesions
- Previously irradiated lesions precluding further external beam irradiation
- Recurrent surgical lesions
- Lesions requiring difficult surgical approaches
- Patients who are too frail for surgery or refuse surgery
- Short life expectancy

Clinical Benefits

- Staged/Fractionated Radiosurgery
  - 1-5 fractions/stages
  - Larger lesions
  - Lesions next to critical structures/organs at risk
- Improved Patient Quality of Life
  - Short treatment course: 1-5 days CyberKnife
  - Optimal for patients with limited life expectancy
  - Increased convenience
  - No infection risk
  - No general anesthesia
  - Minimal to no recovery time

Overview (as of December 2004)

- Over 10,000 patients treated worldwide by CyberKnife
- Over 100 peer-reviewed clinical & technical papers published
- Types of lesions treated by CyberKnife

<table>
<thead>
<tr>
<th>Lesion Type</th>
<th># Patients</th>
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<tbody>
<tr>
<td>Intracranial</td>
<td>7,192</td>
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<tr>
<td>Spine</td>
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<tr>
<td>Lung</td>
<td>466</td>
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<tr>
<td>Nasopharynx</td>
<td>415</td>
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<tr>
<td>Head/Neck/ENT</td>
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<tr>
<td>Pancreas</td>
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<tr>
<td>Liver</td>
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<tr>
<td>Bone</td>
<td>79</td>
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<tr>
<td>Prostate</td>
<td>54</td>
</tr>
<tr>
<td>Others, i.e. kidney, pelvis, etc</td>
<td>447</td>
</tr>
</tbody>
</table>

Spinal Radiosurgery

- Classically radio-resistant tumors: renal cell and melanoma
- In previously radiated fields to avoid myelotoxicity

CyberKnife® Radiosurgery System

- Broad clinical application
  - Intracranial radiosurgery
  - Extracranial radiosurgery
    - Spine
    - Lung
    - Liver
    - Pancreas
    - Prostate
    - Other
- Superior accuracy
- Superior conformality
- Proven clinical experience
  - Over 10,000 patients worldwide
  - Over 100 papers published

Other Clinical Applications

- Primary & Recurrent H&N Cancers
- Lung Tumors
- Liver Tumors
- Para-aortic & Intra-abdominal tumors
- Pelvic tumors
Fractionation

- Used when large tumor volumes are involved
- In intracranial 3-5 fractions employed for volumes of 40-50 ml.
- Fractionate to preserve important functions where the integrity of involved critical structures is of paramount importance. Such as acoustic neuromas and visual acuity in cranial base meningiomas

Trilogy

- Trilogy™ system can be used to deliver 3D conformal radiotherapy, IMRT, stereotactic radiosurgery, fractionated stereotactic radiation therapy, and intensity-modulated radiosurgery for cancer and neurosurgical treatment.

Trilogy (cont)

- 23EX Clinac® linear accelerator, which has been enhanced for stereotactic applications that involve delivering higher doses of radiation to smaller areas over a shorter period of time.
- The Trilogy system is capable of delivering stereotactic radiosurgery by increasing its maximum dose delivery rate from 600 to 1000 monitor units (MU) per minute and by fine-tuning the Clinac isocenter, or focal point, to a 1-millimeter diameter sphere

Trilogy (cont)

- First patient treated in October of 2004
- Uses an On-Board Imager® to acquire images in real time
- Can treat both intra-cranial and extra cranial lesions
- Uses an array to treat extracranial lesions

Other SRS systems

- Trilogy® Stereotactic Beam on Linac

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Synergy

- Elekta Synergy® S will integrate high resolution beam shaping, stereotactic target localization utilizing Elekta® XVI (X-ray Volume Imaging) technology, and organ motion control. Instead of the usual multi-leaf collimator (MLC), Elekta Synergy® S will feature Beam Modulator which allows much finer resolution beam shaping.

- The combination of Elekta Synergy® with other purpose designed framing and fixation products will result in a clinically meaningful stereotactic solution for the localization and hypofractionated treatment of targets, both intra and extra-cranially. For single fraction intra-cranial treatment, the Gold Standard remains Leksell Gamma Knife®.
Nursing Implications

• Side effects, as with any type of radiation therapy, are limited to the area being treated.
• Prudent that the nurse in the radiosurgery suite review with the patient the side effects they may experience and pre-medicate the patient appropriately with anti-emetics or pain medicine as appropriate.
• For example patients receiving CyberKnife® to the lower thoracic and lumbar spine should receive pre-medication for nausea and education that nausea, vomiting, diarrhea or abdominal cramping are potential side effects to treatment of this area.

Nursing Implications

• Pain management becomes important for nurses in radiosurgery suite especially those patients being treated for spinal lesions.
• Treatment can take anywhere from 30-2 hours and having a patient lie in position for that long a period may cause significant pain and discomfort.