Image Guided Radiation Therapy for SBRT

George Ding, Ph.D
Department of Radiation Oncology
Vanderbilt University

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Purpose

- To learn image techniques used in IGRT
- To show the benefit and advantages of IGRT
- To learn the achievable accuracy with a state of the art image guidance system.
- To know the important of QA procedures in order to obtain the accuracy

Introduction

- Image-guided radiation therapy (IGRT) is now the standard of care
- There are many benefits of IGRT
  - Improving the geometric accuracy of patient positioning for radiation delivery
  - Enabling highly conformal target treatment
  - Delivering extremely high dose in a single fraction treatment with frameless
- How accurate can we achieve with a current state of the art image guidance system?
  - Experimental phantom measurements
  - End-to-End patient data

Dedicated Devices

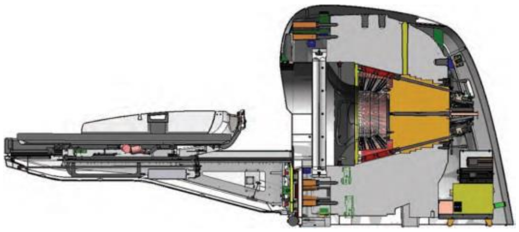

Fig 1. Cut away view of the Gamma Knife Perfexion (ICRU-91)

Imaging systems

The currently available technologies to perform IGRT can be divided, according to their operation into (ICRU-91):

- Planar systems
- Volumetric systems
- Non-radiographic systems.

Planar systems

- Electronic portal imaging devices (EPIDs)
- Stereoscopic x-ray imaging
- These systems allow matching of planar images with DRRs from the planning CT
- kV-beam stereoscopic devices use angled x-ray tubes, corresponding opposed flat panels

Planar systems: Ceiling mounted x-ray tubes

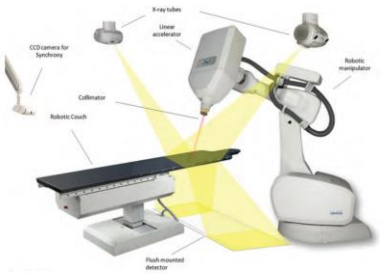

Fig. 2 The CyberKnife™ system with its main components including IGRT systems. The stereotactic x-ray systems have ceiling mounted x-ray tubes and floor-mounted detectors. The x-ray systems are supplemented with a ceiling-mounted camera to determine the patient surface contour. (from ICRU-91)

Planar systems: Floor mounted x-ray tubes

Fig. 3 The ExacTrac™ system with floor-mounted x-ray tubes and ceiling-mounted flat panel detectors (from ICRU-91)

Volumetric systems

- In-room CT: CT-on-Rails
- kV–CBCT: Linac-integrated
- MV-CBCT: Linac-integrated
- MVCT: Tomo
- 3D ultrasound
- Linac MRI

Examples of volumetric systems:

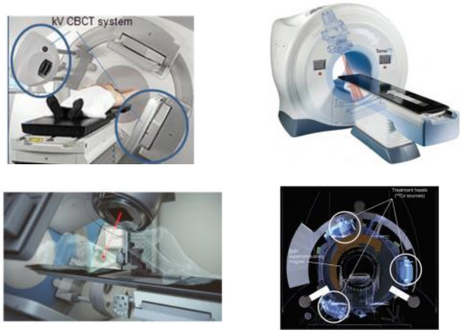

Fig. 4 kV-CBCT, MVCT, Ultrasound and MRI based systems (from ICRU-91)

Workflow SBRT

Planning image acquisitions

⬇

Treatment planning and target delineation

⬇

Quality assurance

⬇

Treatment delivery

Quality assurance

- The aim is to ensure the safest and highest achievable accuracy
- The goal is to reduce the uncertainty in SRT treatment and to set an error tolerance limit for SRT treatment
- Overall uncertainty is combination of:
  - **target location**
  - **dosimetry in the treatment-planning system**
  - **radiation treatment delivery system**
  - **image-guidance system**

Achievable accuracy with a state of the art system

- An example with cranial SRS treatment
- A LINAC based frameless system
- Based on real patients post MRI scans
- Overall uncertainty: End-to-end positioning accuracy

How do we know the End-to-End Accuracy

- Phantom measurements: accuracy may not be applicable to real patient
- Real patient: if position of dose delivered is visible in post-treatment images
- Post-treatment MRI analysis: After delivery of a high dose (>145 Gy) a small enhanced area will form at the treated target and can be visualized on the MRI scan

High dose >145 Gy → Area received the high dose can be seen in the post MRI images

The treatment plan to treat thalatomy: 145 Gy

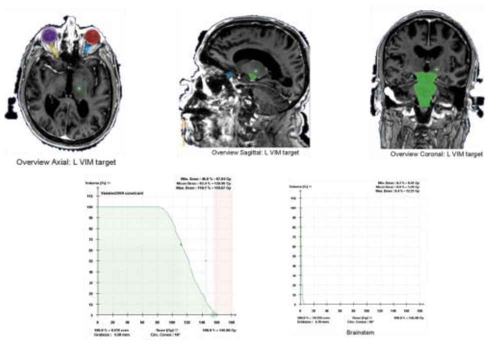

Fig 5 Treatment planed dose distributions and DVHs.

The treatment plan delivers 145 Gy

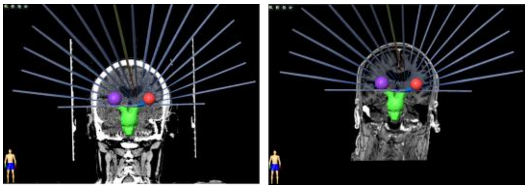

Fig 6 illustration of a treatment plan that has 18 couch positions and 20 arcs. It uses total of 40149 MUs

During the treatment delivery image verification procedures performed

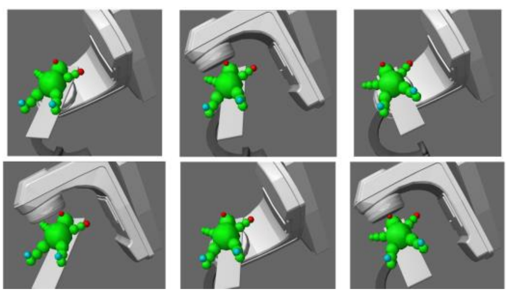

Fig 7 Patient position is adjusted and verified at each table position for each arc before beam delivery .

Imaging system isocenter check

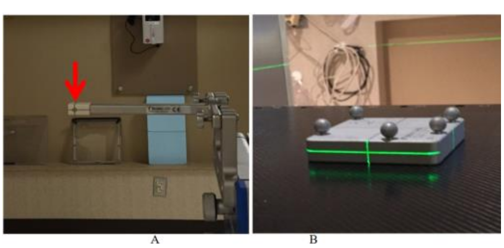

Fig 8 (A) Winston-Lutz test setup testing Linac isocenter (B) ExacTrac isocenter setup;

Typical results from the isocenter check

C D

Fig 9 (C) Validation of image system isocenter accuracy by using Winston-Lutz phantom at Couch angle 180° and 270°. (Luo et al. 2017, Pract Radiat Oncol 7 (3):e223-e231)

Treatment Delivery

- Single dose: 145 Gy (Thalatomy treatment)
- Immobilization: Frameless mask
- LINAC: Varian TX linear accelerator
- Accessary: 4 mm circular cone
- Imaging system: Brainlab ExacTrac system
- Tolerance limit: Errors in the fusion result should be within 0.5 mm and 1°

Initial patient positing before treatment

Fig 10 Initial isocenter setup and target potion verification with the localizer box before x-ray imaging guidance.

X-ray image guided patient positioning during treatment

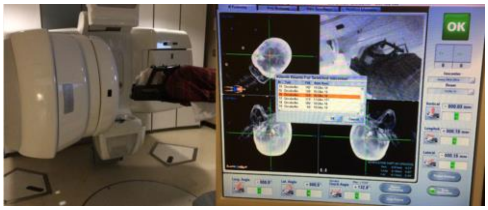

Fig 11 Initial isocenter setup and target potion verification with the localizer box before x-ray imaging guidance.

X-ray image fusing for patient position verification

Fig 12 Two screen captures showing: (Left) a pair of X-ray images from the ExacTrac system obtained and compared with (right) DRRs generated from the planning CT. The image fusion can be done automatically or manual until the best match are found. The fusion results are reviewed before each beam delivery. Tolerance limit: 0.5 mm and 1°.

Pre- post treatment MRI images

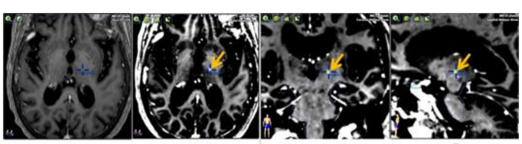

Fig 13 The blue cross shows the original isocenter position; the green circle is the original treatment target; the yellow arrows point to the post-treatment lesion. A: Pre-treatment axial view; B to D: Post-treatment axial, coronal and sagittal views, respectively. (Luo et al, 2017)

- Based on 8 patients post MRI scan (Luo et al, 2017)
- Overall uncertainty: 1.1 mm (range 0.4 mm to 1.5 mm)

Advantages of Imaging guided system

- Patient anatomy based alignment.
- Compensation for couch position uncertainty known as table walk.
- Patient comfort with Frameless immobilization system.
- Reproducibility of inter- and intra-fraction patient setup.
- The accuracy achieved relies upon QA procedures to reduce overall uncertainty
- including image system!

Accuracy with current image guidance system

- To obtain the achievable accuracy requires QA procedures to reduce overall uncertainty in each of the following:
  - target location
  - dosimetry in the treatment-planning system
  - radiation treatment delivery system
  - image-guidance system

Thank you!