Technical aspects of imaging used for IMRT 2: IGRT

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Peter MacCallum Cancer Centre

Regional Training Course on Basics of Intensity Modulated Radiotherapy
Melbourne Australia, 9-13 September 2015
Local control

Identification of the target

Delivery of radiation

Excellent dose distribution

Precision targeting

IMRT

IGRT

Not part of the lecture

The aim of radiotherapy
Evolution of external beam radiotherapy

- Fixed SSD RT
- Isocentric RT
- Conformal RT
- IMRT, VMAT
- IGRT, Motion management
- SABR/SBRT
- Computer planning
- 3D planning
- Inverse planning
- 4D planning, adaptive re-planning

Better set-up
Better targeting
Better sparing
Less patient variability
Margin reduction

Time
Objectives of the presentation

• To introduce basic concept of verification imaging for 3DCRT and IMRT
• To discuss different methods of IGRT
• To introduce imaging tools in the treatment room
• To discuss the clinical role for IMRT/IGRT
The problem

- Linac co-ordinate system fixed in the room (about 1mm accuracy!)
IGRT definition is not universally accepted: Where does it start? Where does it end?
IGRT definition is not universally accepted:
Where does it start?
Where does it end?

General agreement that IGRT involves imaging that can show the target at point of delivery in treatment position, can be repeated daily and allows accurate decision making…
Implementation of the plan

- Transfer of data between units
Implementation of the plan

- Transfer of data between units
- And check it every day
Image guidance

• Support ‘act’ for
  – 3D CRT
  – IMRT
  – SABR/SBRT

• Integral part of
  – Motion management
  – Adaptive RT
Image Guidance

• First X-ray in Australia (July 25, 1896)
• Bathurst: Father Slattery takes image of Eric Thomson’s hand.
• Eric Thomson had accidentally be wounded by a spring gun
Image guidance for RT

- At the time of delivery
- Must visualize the target (or relevant organ at risk)
- Must allow clinical decision making

3 gold fiducials implanted into the prostate gland
Image guidance for RT

- At the time of delivery
- Must visualize the target (or relevant organ at risk)
- Must allow clinical decision making
- Is not necessarily requiring an “image”
Tools for IGRT

- Visualization tools:
  - External (Lasers, markers)
  - Internal (Seeds)
  - US
  - EPID, portal imaging
  - kV imaging
  - CT
    - Cone beam CT
    - CT on rails
    - MVCT
  - MRI?
External markers

- Placed on patient (direct or bite block)
- Monitor patient motion or a surrogate to internal organ motion
- Often used as surrogate markers for breathing motion
Infra-Red Guided Radiosurgery
Z-med system

- Infrared camera establishes spatial correlation
- 3D ultrasound images
Electronic Portal Images

- A filmless way to verify field location
- Standard on most linear accelerators
- Uses the treatment beam for imaging
  - Suboptimal image quality
  - Can be enhanced through use of fiducials
  - Verification of the actual delivery
Fiducial markers can help

- Trade-off – CT artefact vs EPID visibility
- Increasing in use as fiducial marker implantation becomes possible in more sites (lung, liver, head and neck, …)

Courtesy R Owen
There are limits to portal imaging image quality due to MV.

MV portal image of breast phantom

On-board imaging

EPID

Courtesy D Willis
There are no limits to image quality using diagnostic kV

Surgical Clips in the Breast

MV portal image  

kV OBI image  

Courtesy D Willis
From 2D to 3D

On-board imaging

EPID
Cone beam CT

- Each OBI is one ‘multi’ slice CT projection
- Slow scan – motion artefacts
- Field of View limited
- Scatter affects accuracy of CT numbers
Why are the images not as good as fan beam CT?

- Scatter
- Beam hardening
Why are the images not as good as fan beam CT?

- Scatter
- Beam hardening

Fan beam CT has adapted to the challenge by using a narrow beam and high filtration.
Other X-ray image guidance solutions

Siemens in-room CT

Protons at PSI

Brainlab Exactrac

Tomotherapy MVCT
Hybrid MRI accelerator system

Requires system integration: accelerator and MRI system have to operate simultaneously and independently.

closed bore high field MRI
gantry ring based 6 MV MLC accelerator
Does it make a difference?

Like most veterinary students, Doreen breezes through Chapter 9.
What can we do with the images...

- Position the patient, target, or organ at risk
- Modify the treatment plan or choose an appropriate plan
- Detect changes in patient or tumour size

Adaptive radiotherapy for bladder cancer: choice of three plans for the day.

Courtesy F Foroudi and J Wong
**IGRT in “Big Picture”**

- **Therapy Design**
- **Clinical Objective**
- **Intervention**
  - Correct setup error or tumor shifts (couch shift)
  - Replan
  - Stop or change overall plan...
- **Monitoring**
- **IGRT**
- **Imaging**
  - Planning
  - Delivery
- **Real-time**
  - Off-line
  - On-line

L Dawson 09
Internal anatomy is changing

Start of treatment

7 days later

2 weeks later

3 weeks later

1 month later

Courtesy of Tim Holmes, St. Agnes Cancer Center, Baltimore, MD
Re-optimisation - adaptation

- Good images during treatment allow re-planning
- Needs to be based on original patient set-up
- On line? Off line?
How to adapt after IGRT?

• **Individual patients**
  – Position (each image)
  – Margins (multiple images)
  – Re-optimise

• **All patients (requires database)**
  – Margin recipes
  – Decision making rules
Image guidance

• Provides powerful information on:
  – Fractions
  – Individual patients
  – Groups of patients
  – Treatment units
  – Planning processes
  – Departments
  – …
What can we do with the images…

- Position the patient, target, or organ at risk
- Modify the treatment plan or choose an appropriate plan
- Detect changes in patient or tumour size
- Change clinical practice

Adaptive radiotherapy for bladder cancer: choice of three plans for the day.

Planning PTV

large
average
small
Rectum

Courtesy F Foroudi and J Wong
What can we do with the images…

- Position the patient, target, or organ at risk
- Modify the treatment plan or choose an appropriate plan
- Detect changes in patient or tumour size
- See more than anatomy

Adaptive radiotherapy for bladder cancer: choice of three plans for the day.

Courtesy F Foroudi and J Wong
Daily CT for adaptive radiotherapy

Week 1

3cGy + 3cGy + 3cGy + 3cGy + 3cGy + ...

Week 2

3cGy + 3cGy + 3cGy + 3cGy + 3cGy + ...

3cGy + 3cGy + ...

repeats
Dose from CBCT

- Dose from CBCT*:
  - Mostly half fan with copper filter
  - Sup inf coverage 20cm
  - Assume equal dose wherever beam, no dose outside
  - Assume 30mGy
- Include repeat and QA scans (eg re-image after voiding)

* Roxby et al. BJR 2009
Dose?
More imaging versus smaller fields…

Conventional

One of the adaptive plans

Daily CT for adaptive radiotherapy
Difference in dose

Conventional RT less dose

Adaptive RT gives less dose
A few final words on PET

Courtesy M MacManus
Treatment response can reveal unwanted results

Pre-treatment

Mid-treatment (1 wk of XRT)

Courtesy R Jeraj
Treatment response can reveal unwanted results

Pre-treatment

Mid-treatment
(1 wk of XRT)

Courtesy R Jeraj
Elements of IGRT

- Clinical needs are the driver
  - Equipment
  - Processes
  - Communication
  - Training
  - Quality assurance
Development and evaluation of a training program for therapeutic radiographers as a basis for online adaptive radiation therapy for bladder carcinoma

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Received 14 April 2009; revised 4 August 2009; accepted 7 September 2009
Available online 12 October 2009
Summary

• Imaging has changed the way we think of radiotherapy
  – Planning
  – Treatment
• High quality RT requires imaging
• Exquisite dose distributions can be created using IMRT (or one of its many forms)
• The combination of both makes modern RT powerful

Arcimboldo
Consumer Report

• Visualisation tools:
  – External (Lasers, markers)
  – Internal (Seeds)
  – US
  – EPID, portal imaging
  – kV ‘on board imaging’
  – CT
    • Cone beam CT
    • CT on rails
    • MVCT
  – MRI?
## utility

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*Personal score – neither representative nor useful*
## Clinical utility

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Review

The European Society of Therapeutic Radiology and Oncology–European Institute of Radiotherapy (ESTRO–EIR) report on 3D CT-based in-room image guidance systems: A practical and technical review and guide

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ARTICLE INFO

Article history:
Received 31 October 2009
Received in revised form 8 January 2010
Accepted 16 January 2010
Available online 12 February 2010

Keywords:
3D volumetric imaging
Cone-beam CT
Image-guided radiotherapy
kV CT
MV CT
Quality assurance
Radiotherapy

ABSTRACT

The past decade has provided many technological advances in radiotherapy. The European Institute of Radiotherapy (EIR) was established by the European Society of Therapeutic Radiology and Oncology (ESTRO) to provide current consensus statement with evidence-based and pragmatic guidelines on topics of practical relevance for radiation oncology. This report focuses primarily on 3D CT-based in-room image guidance (3DCT-IGRT) systems. It will provide an overview and current standing of 3DCT-IGRT systems addressing the rationale, objectives, principles, applications, and process pathways, both clinical and technical for treatment delivery and quality assurance. These are reviewed for four categories of solutions; kV CT and kV CBCT (cone-beam CT) as well as MV CT and MV CBCT. It will also provide a framework and checklist to consider the capability and functionality of these systems as well as the resources needed for implementation. Two different but typical clinical cases (tonsillar and prostate cancer) using 3DCT-IGRT are illustrated with workflow processes via feedback questionnaires from several large clinical centres currently utilizing these systems. The feedback from these clinical centres demonstrates a wide variability based on local practices. This report whilst comprehensive is not exhaustive as this area of development remains a very active field for research and development. However, it should serve as a practical guide and framework for all professional groups within the field, focussed on clinicians, physicists and radiation therapy technologists interested in IGRT.

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