Learning Objectives

After this lecture the attendees should have

• A better understanding of Patient Positioning Systems (PPS)
• Knowledge about state of the art Patient Alignment Systems (PAS).
• Understand the needs for new thinking towards patient positioning for proton therapy.
IGRT + Proton Therapy

• Proton Therapy introduced Image Guided Radiation Therapy (IGRT) to the field of Radiation Therapy.

• Protons have always been delivered while using some sort of imaging during the setup process.

• However – today Ion Therapy Systems are not properly equipped with IGRT systems as compared to Photon therapy systems.
The Radiation Therapy Process – Control diagram

Most of the time spend here
What is required in the Patient Alignment Process?

- **Patient Positioner**
  - to move the patient accurately into position
  - to keep the patient in position
- **Immobilization system**
- **Imaging + Localization System**
  - to know where the target is
  - to ensure the target remains in position
- **Oncology information System**
  - provide the information
  - track and record the process
Site Setup

Couch Kick (Angle) = 0 Degrees

Position patient for setup field

Record Couch Kick off-sets

Treat

Save Field 1 position

Move isocentrically to next field

In Position

Apply Couch Kick offset to Couch angle

Position patient for field 1

Not in Position

In Position

Move isocentrically to next field

Not in Position

Record Couch Kick off-sets

Move isocentrically to Field 1

In Position
Patient Alignment Workflow

Site Setup

Couch Kick (Angle) = 0 Degrees

Two discretely separate processes

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Patient Alignment Workflow

Two discretely separate processes

Indexing

Surface tracking

Optical tracking

Bite Blocks

CBCT

+ X-Rays

Verification techniques

Surface tracking

Optical tracking

External Surrogates

X-Rays if needed

Need Confidence in the PPS + Gantry
Immobilization

• Some Paradigm shifts are required
  – Masks
  – Positioning devices

• Patients move during treatment
• Immobilization devices often provide a false sense of security
• Its easy to blame the PPS but did the patient perhaps move?
Some Paradigm Shifts Required - Masks

Perforated Thermoplastic masks are;
- Required in X-ray therapy to preserve the skin dose
- Not very sturdy

Thermoplastic masks for IONS;
- Does not affect the skin dose
- Can be thicker and more rigid.

In ION Therapy the skin dose is not affected by the Mask
Some Paradigm Shifts Required – Positioning Devices

Comfortable CT Scanner top

Very Uncomfortable CT Scanner top
1. Neither the roll correction or skin dose is a problem for Ion therapy
2. We should not use flat table tops
3. The LLUMC Pods are probably the right answer
Requirements of a Patient Positioner

- Patient comfort
- Accuracy + Reproducibility
- Patient Safety
- Reliability
- Maneuverability
  - work envelope
  - Motion speed
- Uptime
Custom Made Robotic Positioners

IBA – Shär / General Atomics

Hitachi

Mitsubishi

Downside

Low volumes of production
Expensive
Reliability
First + 2\textsuperscript{nd} Generation: Commercially available Robots

Use Commercially available of Robots as is

With Compliments from CPO

Accuray
2005

Siemens
2005

START
CPO
1997

MPRI
2004

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Third Generation: Everybody now use them

2008 ➔

Almost all Vendors now use a SCARA type Robotic Patient positioner
Advantages of using a Robotic PPS

- Very reproducible – backed by a large industry
- Can couple to different disease site specific devices.
- Are reproducible + can be very accurate
- Can have large work envelopes
- Can be used by Physics in the QA environment →
  - Many more
  - Of course there are also disadvantages
One example ➔ Site Specific Treatment Devices

Remote Anesthesia System
Site Specific Treatment Devices

Anesthesia in the room

System in Clinical in use

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One potential Pitfall - Misalignment of isocenters

It does not matter how good your PPS is – if the IGRT + PPS devices in the treatment room are not properly aligned all the efforts are wasted.
Next Steps – Robotic PPS

• Smarter uses of the Robotic positioners
  – Haptic motions
  – Smart trajectories
  – Vision guidance

• Add tracking software to enlarge useable work envelopes

• Improved calibration methods

• Integrate the PPS better with PAS and Control systems
Imaging System + Localization System

to know where the target is
to ensure the target remains in position

• Requirements
  – Dose to the patient (if ionizing radiation is used)
  – Resolution
  – Accuracy
  – Reproducibility
  – Ease of use / Intuitive user interface
  – Connectivity with OIS
Target Imaging + Localization Techniques – X-Rays

General Techniques
Surface markers – Optical tracking
Mechanical fixation & reference frames → Indexing
kV + MV radiographs & fluoroscopy
Bone
Implanted Fiducial markers
Implantable sensors
Surface recognition

Volumetric / 3D
Ultrasound
MV Tomotherapy
In room CT scanner
Cone-beam CT
Megavoltage
Kilovoltage
MR-guided Linear Accelerator
MR-guided Cobalt-60 Machine
Target Imaging + Localization Techniques – **IONS**

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**In-Situ PET Imaging**

*Adapted from Jatinder Palta*
Overview of PAS Systems

Existing PAS Systems used in Proton Therapy

- Optical Tracking
- Surface Recognition
- Internal sensors
- Ultra Sound
- Planar X-Rays
- Volumetric Imaging
Overview of PAS Systems – Optical Tracking

iThemba Labs – Cape Town
Overview of PAS Systems – Ultra Sound

Clarity - Elekta
Optical Tracking of US probe

Elekta is working on a real time US tracking system for Prostate treatments
Overview of PAS Systems – Orthogonal x-rays
Overview of PAS Systems – Stereoscopic x-rays
Overview of PAS Systems – Fiducial Markers + X-rays

The use of Fiducial Markers - Prostate Grapes

Contour individual Fiducial markers with a 2 mm margin
Place Fiducials in the “grapes” in AP and LAT images

LAT – X-Ray + DRR overlay

AP – X-Ray + DRR overlay
Monitoring and Motion Tracking

• Same Technologies as in X-ray therapy should be used since the problem statement is the same.

• However - motion management is probably more important with Ions.

• Solving the motion problem is “easy” but knowing where the target is at any given moment is the challenge.
Methods of Controlling Respiratory Motion

• Breath hold
  – ABC – *William Beaumont => Elekta*
  – DIBH → MSKCC
  – *Patient self breath hold*

• Gating – *Japanese experience*

• Countermove the entire patient – “let the PPS breath”

• Abdominal Compression
Overview of PAS Systems – Surface Recognition

Stereo Cameras

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Overview of PAS Systems – Surface Recognition

Laser Surface Scanners

C-RAD Galaxy – LAP Laser
Overview of PAS Systems – Varian (Calypso)

Figure 1. Schematic drawing of the TULOC assembly.
Volumetric Imaging

- In the Photon world
  - Volumetric imaging <=> Cone Beam CT
  - Cone Beam CT <=> Image Guidance

- In the Ion Therapy world
  - Volumetric imaging <=> Soft Tissue Definition
  - Volumetric imaging <=> Anatomical characterization
  - Image quality is much more important
  - CBCT only gives a partial answer

- One solution is to use Axial CT Scanners + MRI scanners – Inside or Outside the room
In Room Options – Axial CT Scanner

The SCARA type PPS has a very large work envelope allowing to place a CT scanner in the treatment room.
In Room Options - BodyTom

“CT on Wheels”
Summary

- Patient Positioners based on commercially available robots are now widely adopted by most vendors.
- Unlike photons - Immobilization devices does not impact the skin dose for ion beams.
- The use of disease site specific immobilization and patient positioning devices will improve patient positioning in Ion therapy.