Motion Management in Lung Cancer Radiotherapy

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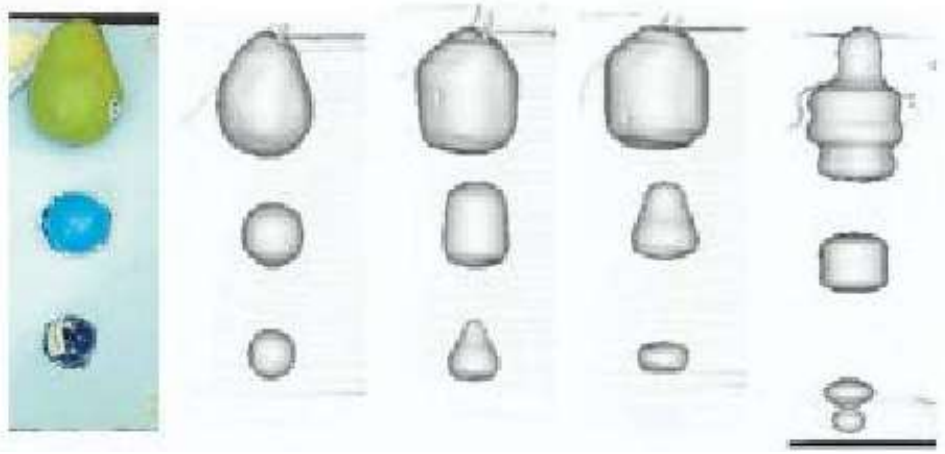
Why?

- Enables more accurate and less toxic treatment

- Relevant for both early stage (stereotactic body radiotherapy) and locally advanced unresectable lung cancers

PROBLEMS WITH STANDARD APPROACHES

- Helical CT scans are very fast, hence like a snapshot of the tumor.
- Difficult to appreciate the full range of motion of the lungs.
- Also, there may be significant distortion of tumor shape & size (motion artefacts)



TECHNIQUES OF MOTION MANAGEMENT IN LUNG CANCER

METHODS OF ASSESSING LUNG TUMOR MOTION DURING RESPIRATION

- Four dimensional computerised tomography (4DCT) / respiratory gated CT scans

- Slow CT scans

METHODS TO CONTROL / COMPENSATE FOR LUNG MOTION DURING RESPIRATION

- Free breathing methods:
- Internal Target Volume (ITV)-based treatment
- Gating
- Tracking
- Breath-hold methods:
- Active Breathing Coordinator (ABC)

ITV-based treatment

- Generates a composite target volume for lung tumors, taking into account the different shape, size and position of the tumor in each phase of respiration

- Can be done on any LA with MLCs or on Tomotherapy , where there is no specialised motion management technology available for treatment delivery.

Gating

- Treatment delivery is done in the phase of respiration where the tumor motion & resulting treatment volume is minimum, by coupling the beam delivery with the phase of respiration
- Usually requires an internal fiducial, implanted within the tumor.

Tumor Tracking

- Imaging is used to track the actual tumor motion during treatment delivery and to move the treatment beam accordingly based on the varying position of the tumor.

- Usually requires an internal fiducial, implanted within the tumor.

- Can also be done non-invasively in some cases.

Active Breathing Coordinator

The patient is coached to breath-hold in inspiration, to eliminate lung motion & treatment is delivered only in this state.

Simulation -Positioning

- For patients due for ITV-based treatment or ABC, conventional CT simulation is done using 3 LASER markers, with radio-opaque fiducials placed on the patient's skin

Positioning & Immobilisation

- Patients are positioned supine with arms above their heads.
- For gating/tracking, external fiducial system (infra-red reflectors) are placed over the patient's thorax and positions marked with indelible ink on the patient's skin.
- For good reproducibility, a photograph of the patient in this position, is then taken.

Simulation-Imaging

- Patients for gating/ tracking/ITV-basedtreatment undergo plain 4DCT scan for planning (3mm slices), using Mayo belt/ Anzai belt/ RPM system to correlate the respiratory phases and corresponding CT images.
- Ten data sets are thereby generated.

- Patients for ABC need not undergo 4DCT scan.

- They can undergo an inhale breath-hold spiral CT scan with/ without contrast.

Delineation: GTV & ITV

- GTV is contoured using lung windows. Mediastinal windows may be suitable for defining tumours proximal to the chest wall.
- Where available, information from PET/CT should be incorporated into delineating the GTV.
- For gating/tracking, tumor delineation is done on the end-expiratory data -set. This is because, in this phase, lung motion is minimum.
- For ITV-based treatment, tumor delineation is done on the end- expiratory data set and extrapolated across the other data sets, to generate the ITV.

Delineation: CTV & PTV

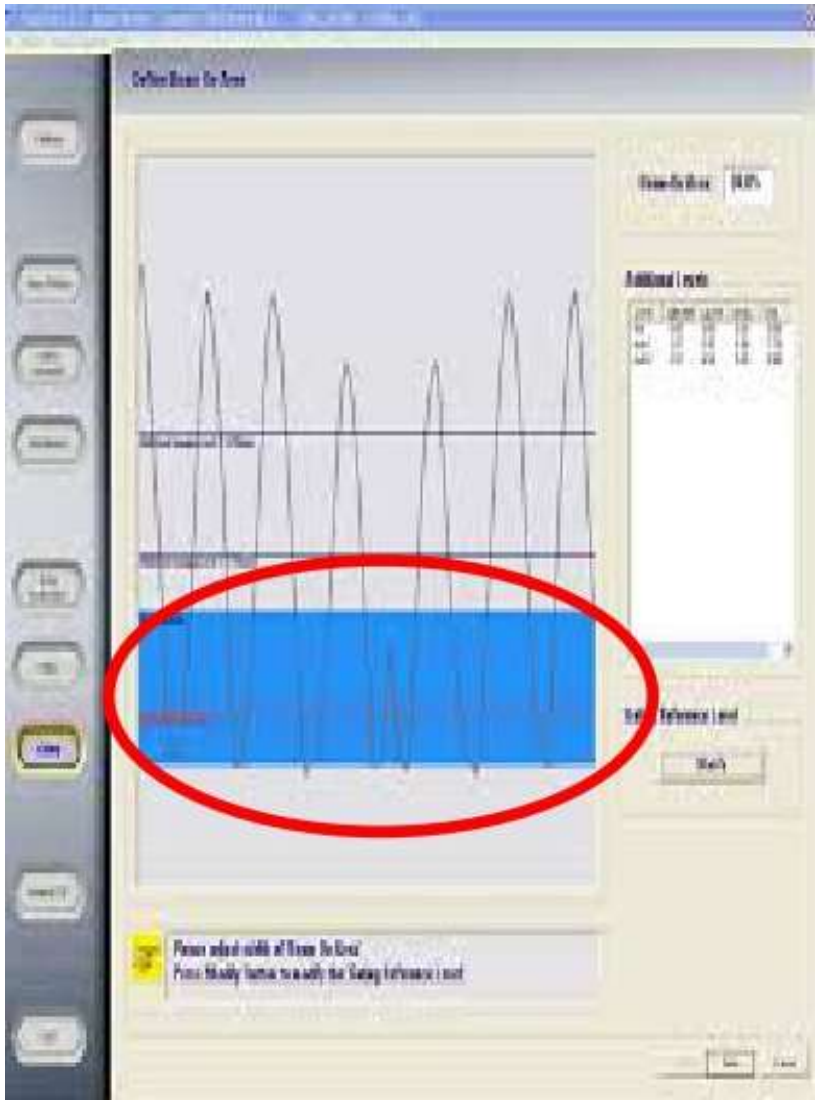
- No CTV margin is given for stereotactic body radiotherapy for early inoperable lung cancers.
- For locally advanced disease, CTV margins between 0.6-0.8 cm are usually applied.
- Setup margins of 0.5 cm are normally applied (to the GTV/ CTV/ITV, as appropriate) to arrive at the PTV

Treatment setup

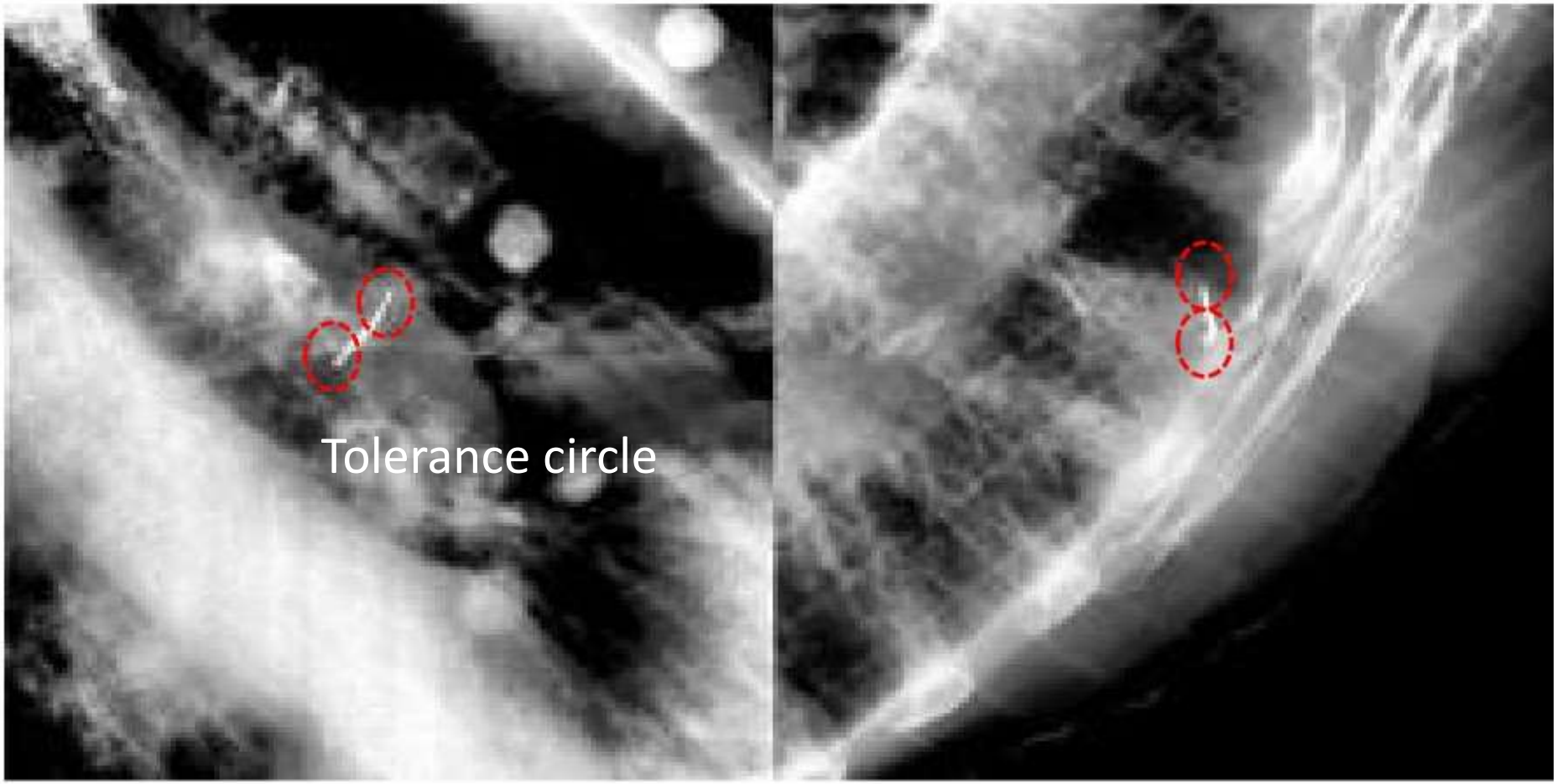
- The patients are positioned accurately by matching LASER fiducials OR Infra-red markers, as for initial simulation.
- Where available, pre-treatment Cone Beam/Fan Beam CT scans are taken & matched with the planning CT scan, for accurate patient positioning.

Gating: Workflow

- Respiratory signal is picked up using IR cameras to pick up the motion of infra-red markers on patient's body and once stable, is correlated with respiratory phase
- The gating window is then set at end-expiration

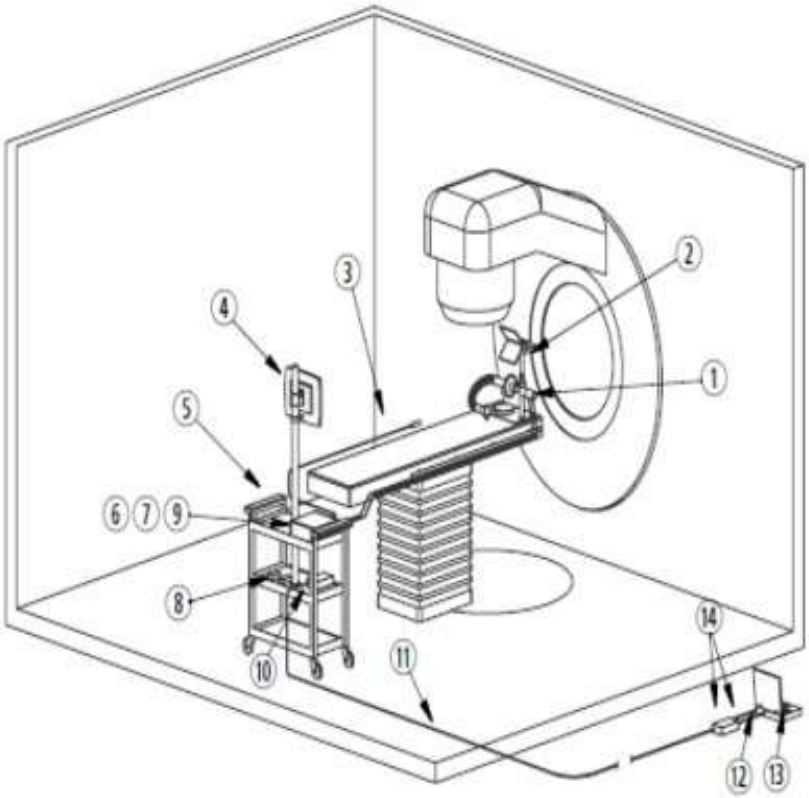


- Oblique image pairs are taken by ExacTrac system's stereoscopic X ray imagers.
- Internal fiducial ends are identified to the system
- The system builds a correlation model between the end-positions and the respiratory phase (accuracy of correlation 3mm).
- The treatment beam is then turned on and is configured to treat ONLY in the gating window.


Tolerance circle

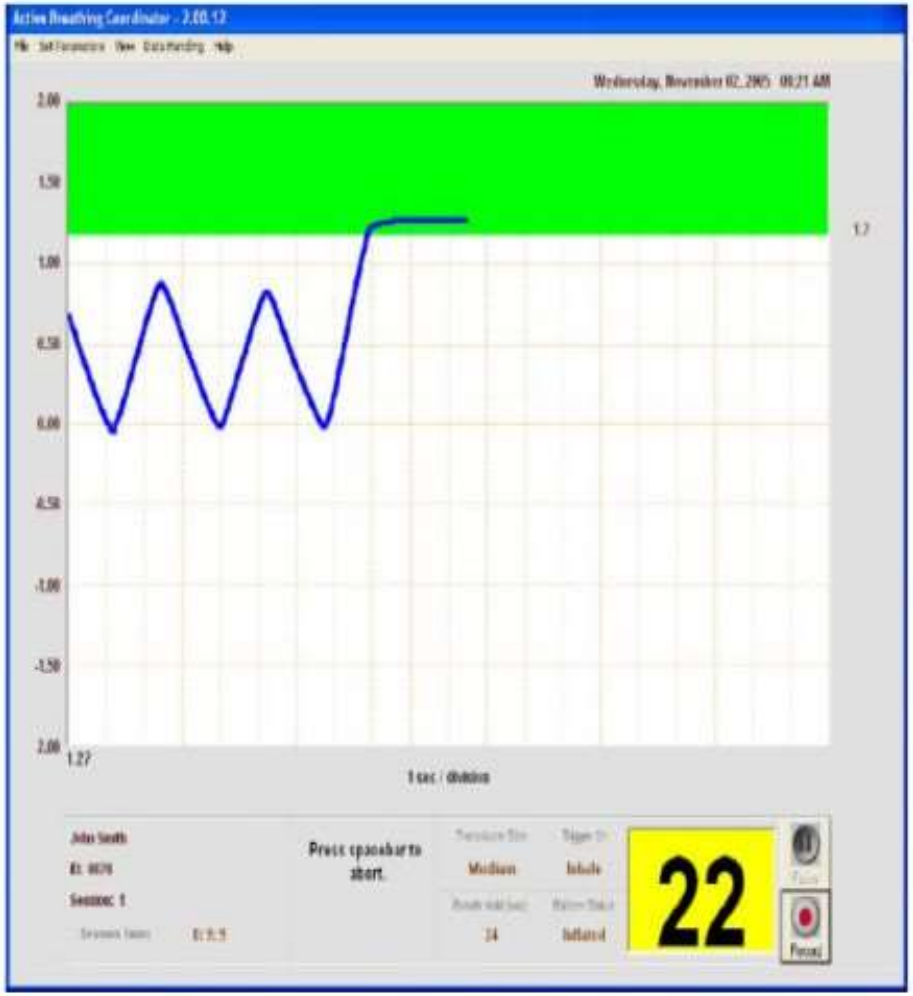
ABC: Principle

- The patient is able to produce an accurate breath-hold to a known volume by observing their own respiratory information on a patient display monitor from the imaging or treatment table.
- Patient coaching prior to imaging or therapy instructs the patient on how to hold their breath at a predefined volume (threshold volume) which is clearly shown on the patient display monitor .
- Accurate and reproducible timing of the breath-hold period is aided by a patient controlled balloon valve that is directly connected to the flow meter device.
- Image acquisition and beam delivery are only performed while the patient is holding their breath to an identical lung volume.



① Patient respiratory system
② Mirror support system
③ Patient control switch
④ Patient feedback monitor
⑤ Cart system
⑥ Control module
⑦ RS-232 serial cable
⑧ Power supplies
⑨ Power cordset
⑩ PC Extender System-receiver
⑪ Category 5 UTP Cable
⑫ RS-232 serial cable (console area component)
⑬ Control computer (console area component)
⑭ PC Extender System-transmitter (console area component)

Figure 2.1 Typical treatment room layout



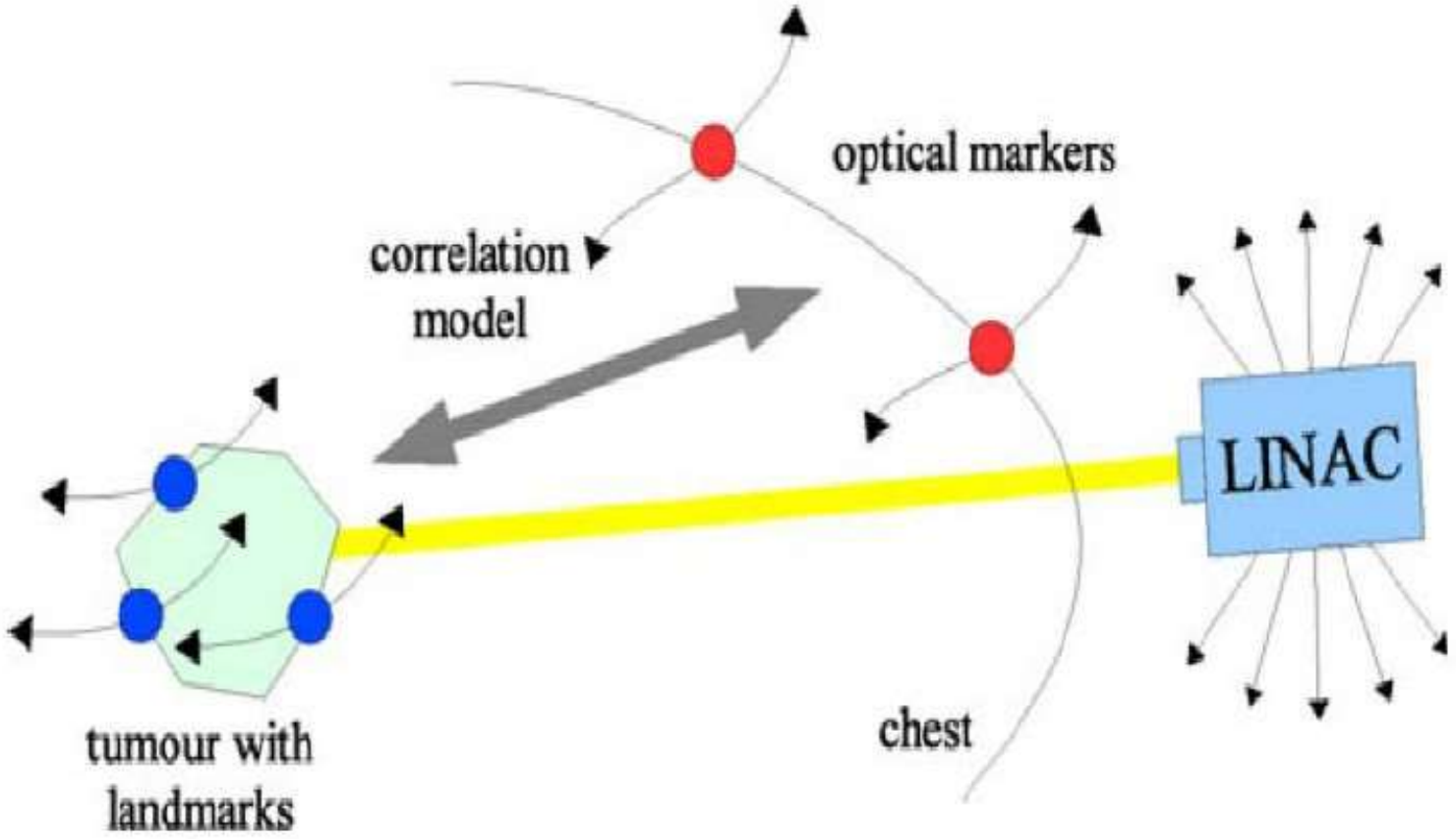
Pros & Cons

- The amount of air that remains in the lungs immediately following a normal unforced exhalation (functional residual capacity) is very stable.
- Proper use of the system requires that the patient is undergoing normal breathing

Real Time Tumor Tracking

- ExacTrac system (VERO) ™
- Cyberknife ™

Principle of RTT



Requisites of Correlation Model

- Accuracy
- Speed
- Minimum imaging dose

Cyberknife: RTT Modes

- **Non-invasive**:

  Xsight lung

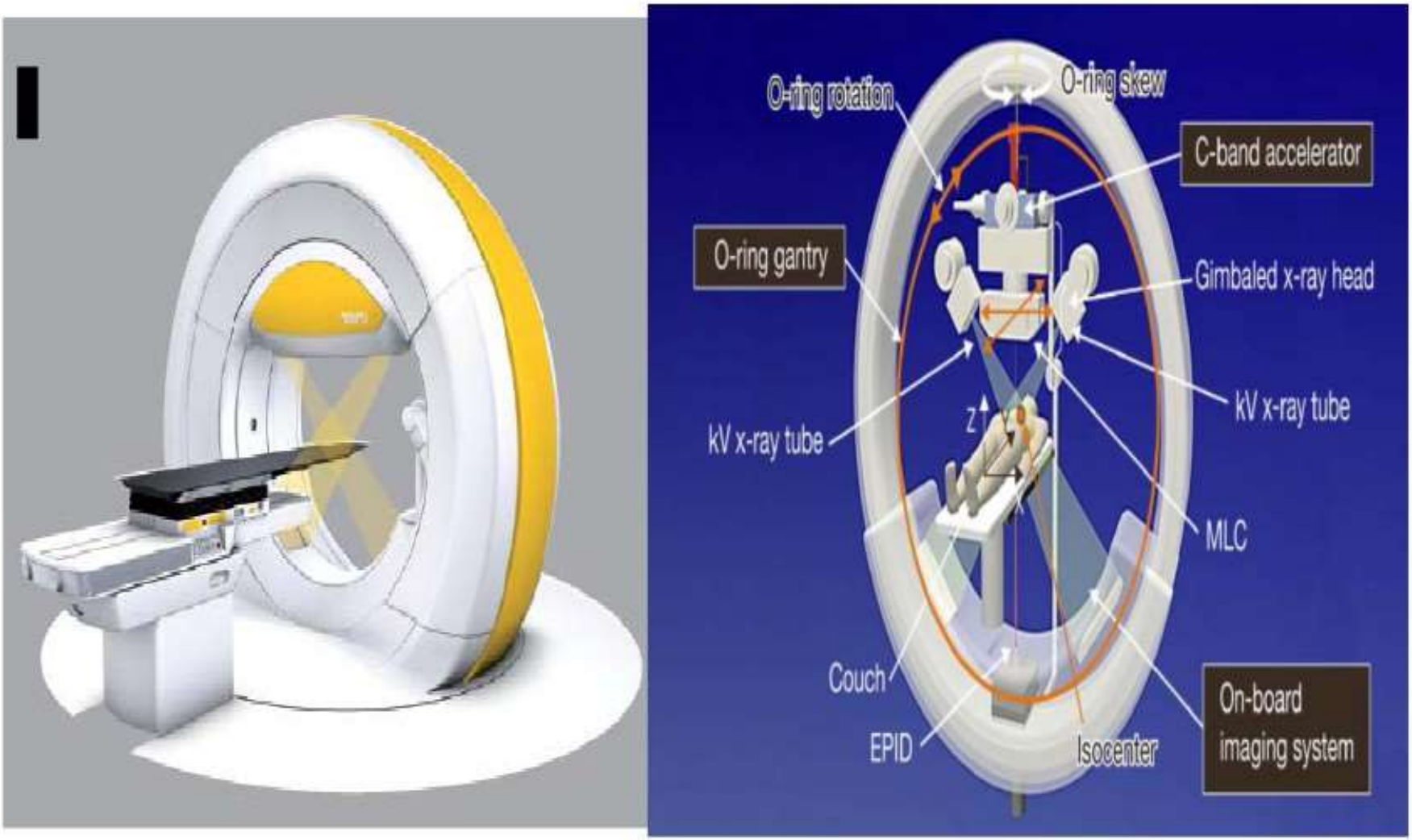
- Possible if:
- Tumour >1.5 cm, surrounded by air
- Tumour visible by imaging system

- **Invasive** (with implanted fiducial):

  Synchrony

- 3-5 fiducial markers need to be inserted in close proximity to the lesion
- They have to be well seperated (>2cm) and non-overlapping on oblique X ray image pairs

VERO (Brainlab-Mitsubishi)



- Has 6MV C-band LA mounted on O-ring gantry
- Gantry is mounted on gimbals
- Capable of pan & tilt motions
- Maximum motion allowed 2.5cm in isocentre plain / 2.5 degrees in each direction

- Has facility for **Cone Beam CT** & **Real Time Tumor Tracking** (based on Infrared & stereoscopic X rays) .
- **6 degrees of freedom**
- Patient repositioning **not** required as the system can move itself
- Image verification possible at any position during treatment

Take Home Points

- Motion is inevitable & irregular
- Can be measured reasonably accurately
- Can be controlled/compensated for/partially eliminated
- Procedures demand sophisticated imaging & complex mathematics
- No single perfect method: free breathing methods aren't the most accurate & breath-hold methods aren't the most comfortable

Thank You