Role of Imaging in Radiation Oncology

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Goal of Imaging in Diagnostic Radiology

- Identification of the lesion
- Characterization
- Staging (local and distant)
- Follow-up
- Interventions (diagnostic and therapeutic)

- Specificity of imaging is crucial
  - Accurate characterization and diagnosis

Goal of Imaging in Radiotherapy

- For Treatment planning & delivery
  - Delineation
  - Relationship with vital structures
  - Treatment planning
  - Simulation and verification of plan

- Sensitivity of imaging is crucial
  - Accurate extent and margin depiction

- Post Treatment Imaging

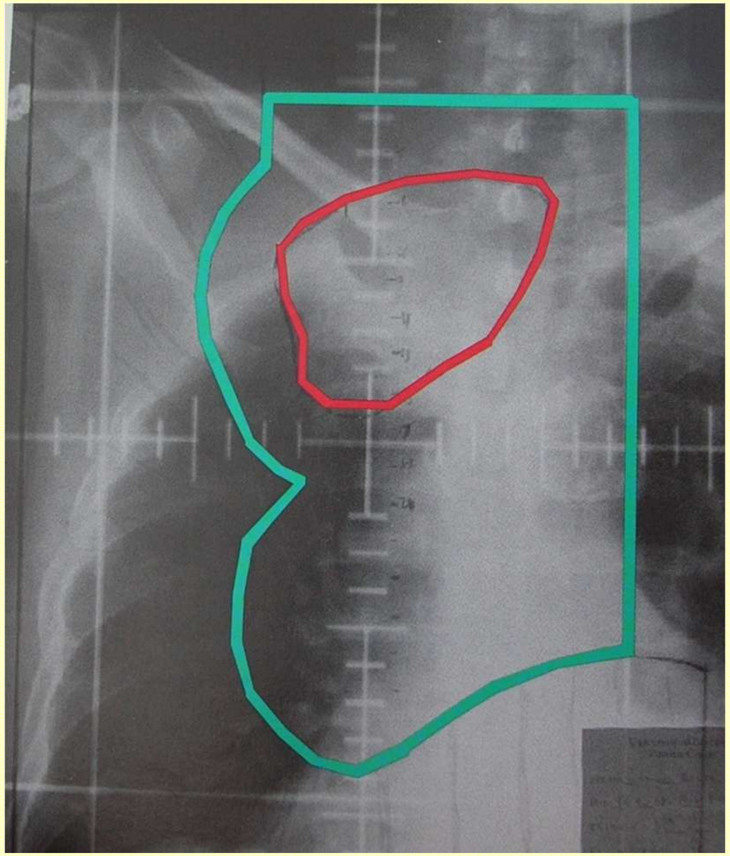
Modalities

- X-ray
- CT
- MRI
- PET

- Ultrasound
- Fluoroscopy

X-rays and fluoroscopy

- Used ever since its introduction
- Simple, cheap, portable
- Only modality available till 1970s
- Perfected with long and extensive use
- Standard technique for conventional simulation



X-rays: Disadvantages

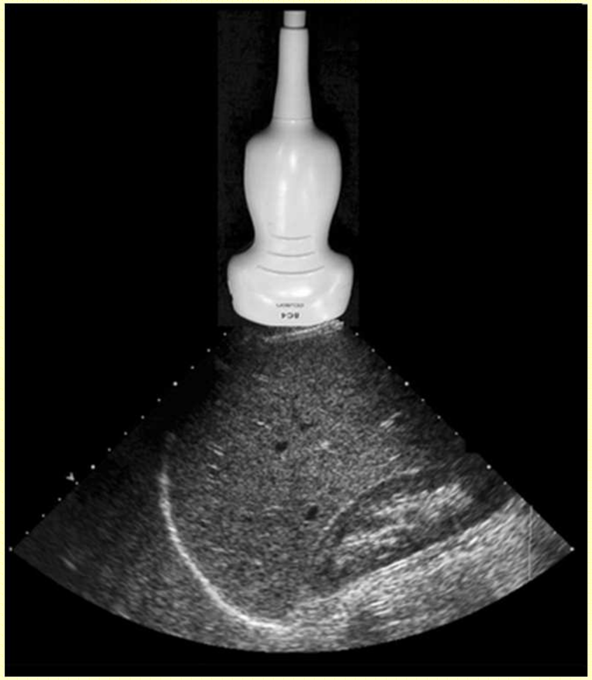
- Two dimensional, everything superimposed
- Requires at least two orthogonal views
- Visualization of tumor or normal structures are inadequate
- Highly susceptible to techniques
  - Positioning, exposure, processing
- Digital X-ray
  - Improved the quality and speed
  - Teleradiology and archiving
  - Integration with other modalities

Cross Sectional Modalities

- Ultrasound, CT, MRI
- Revolutionalized the diagnostic imaging
- Also developed radiotherapy
  - Virtual simulation
  - 3D conformal radiotherapy
  - Intensity modulated radiotherapy
  - Image guided radiotherapy
  - Brachitherapy

Ultrasound

- Ultra high frequency sound waves (2-13 MHz)
  - Generated and received by peizoelectric crystal

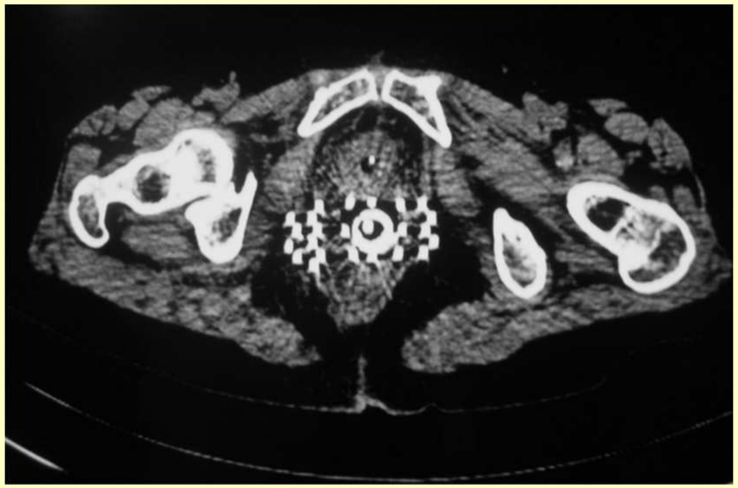


Ultrasound

- Advantages
  - Cheap, portable, widely available
  - No radiation
  - Real time
  - Diagnosis of simple cyst is reliable
- Disadvantages
  - Limited visibility through bone, air
  - Small field of view
  - Highly operator dependant
  - Poor reproducibility

Ultrasound in Radiotherapy

- Not suitable for teletherapy planning
- Has some role in brachitherapy, IGRT
  - E.g. breast, cervix, prostate, lung, liver

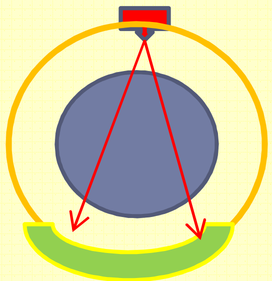


CT

- Most important development since x-ray
- Changed both diagnostic radiology as well as radiotherapy
- Continuous development has increased the speed as well as resolution
- Integration with computer development for 3D display, networking, archiving

CT

- Narrow collimation x-ray beam
- Solid/ gaseous detectors
- Attenuation values in 2D slice planes are plotted for various positions of x-ray source and detectors
- Vast data is generated and integrated by powerful computers



CT

- Complete delineation of anatomy and pathology
- Integration with networking, storage, therapy planning systems and treatment units
- Accurate delineation and planning
- Color coding, virtual simulation (DRR, BEV), verification of multiple plans

Contrast agents in CT

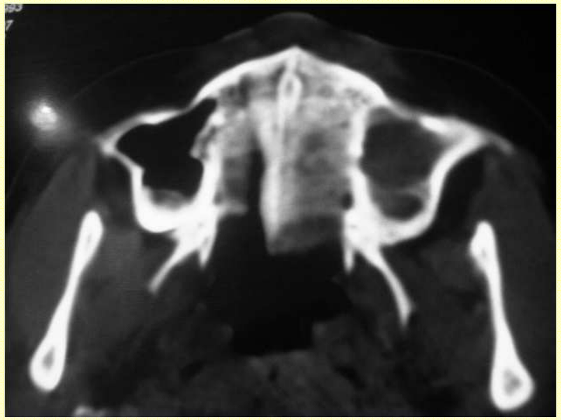
- Standard for diagnostic radiology
  - Improves delineation of tumor
  - Better identification of vessels and bowel
  - Characterize them on basis of enhancement pattern
- Uncommonly used for planning CT
  - Disease and its extent is already diagnosed
- However, it improves tumor visibility and adjacent structures (vessels, bowel) in specific situations
  - Brain, abdomen

CT Technique

- Positioning
  - Flat table
  - No gantry tilt
  - Alignment of immobilization devices, fiducials
  - Laser markers for isocenter alignment

CT Technique

- Large FOV
- Correct selection of scanning parameters
  - KV, mA, slice thickness, reconstruction algorithms
  - Window width and center
- Standard protocols are helpful
- Contrast opacification if required

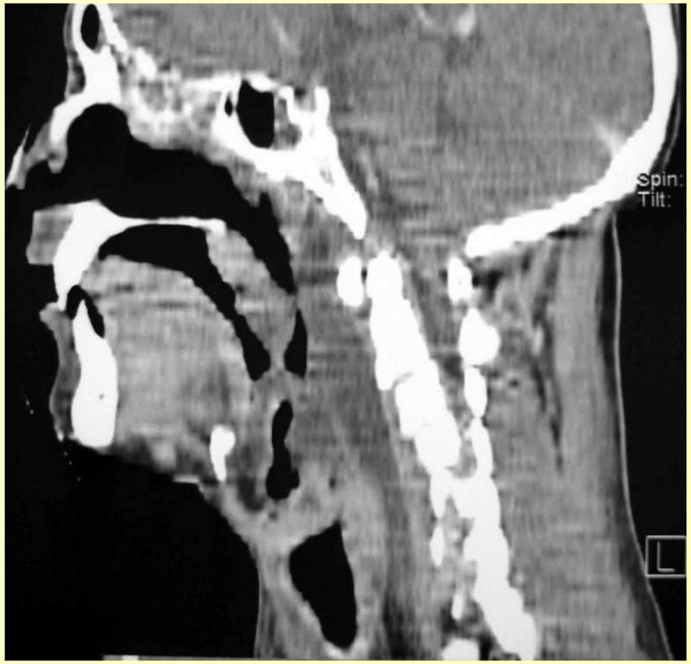


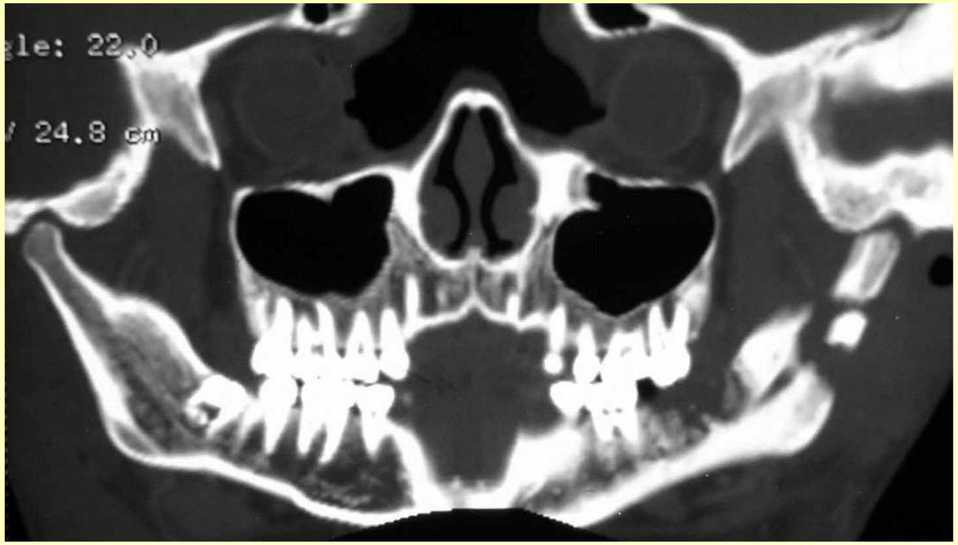
3D Imaging

- Important component of 3D CRT, IMRT, IGRT
- Processing of 2D CT/MRI images
  - Various projections and display modes
- Allows segmentation
  - Tumors, organs, their margins and tissue planes evaluated from various angles
  - Correlation with landmarks, fiducials (markers/ frames)

MPR

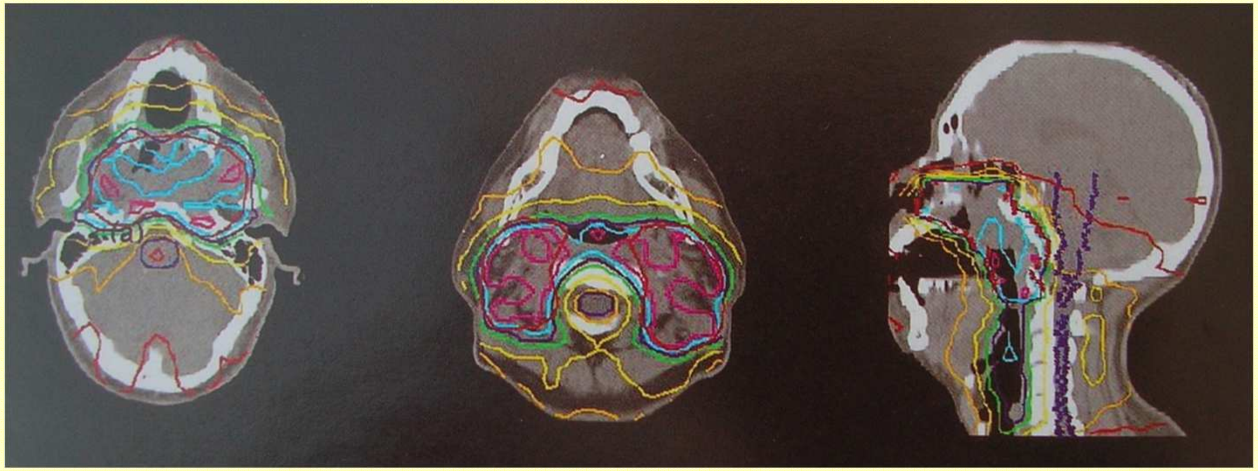
- Slice in planes other than axial
  - Coronal, sagital, oblique, any other





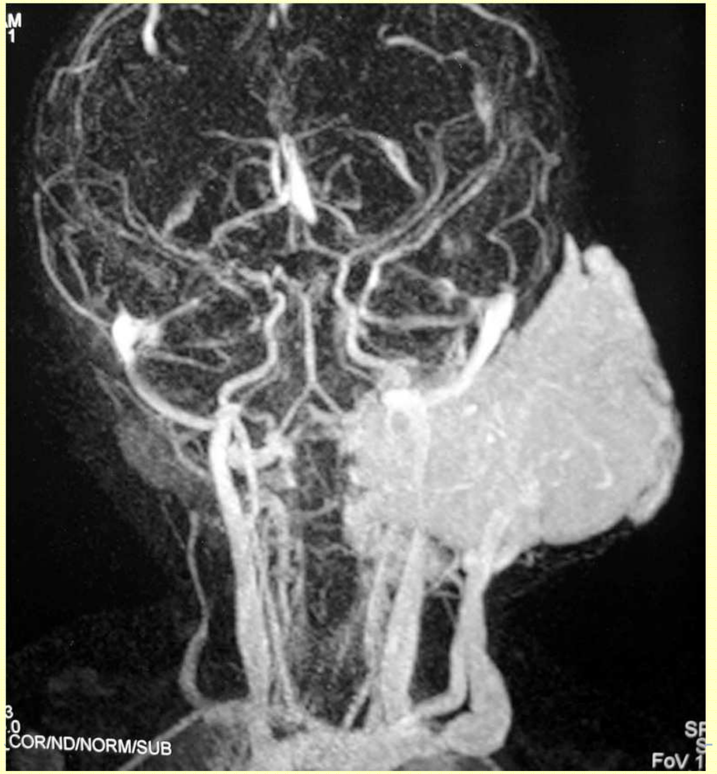
MPR

- Good delineation
- Can take any 2D plane in a 3D space
  - Dose distribution curves can be plotted
  - Fails to integrate information from adjacent plane
  - Superimposition of the plan is not possible



Volumetric

- Shaded surface display (SSD)
- Maximum intensity projection (MIP)

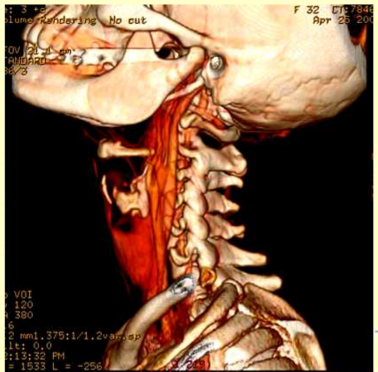


Volume rendered (VRT)

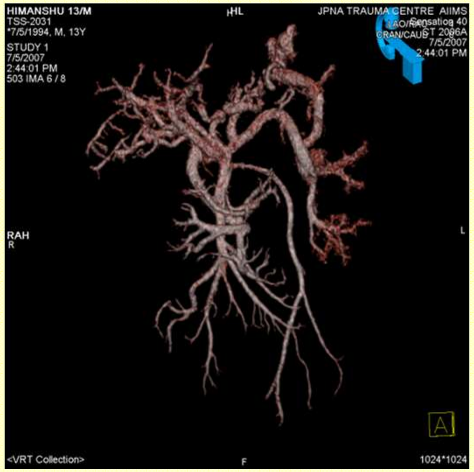
- 3D model with various degree of opacification
- Uses opacity transfer function from fixed observer viewpoint
- Color coding





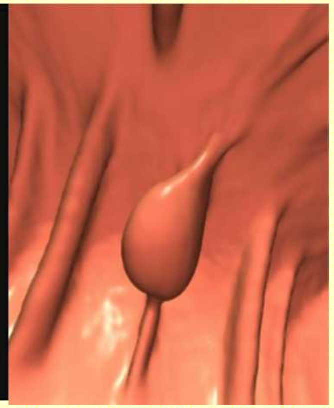
CT: Image Depiction



CT: Image Depiction





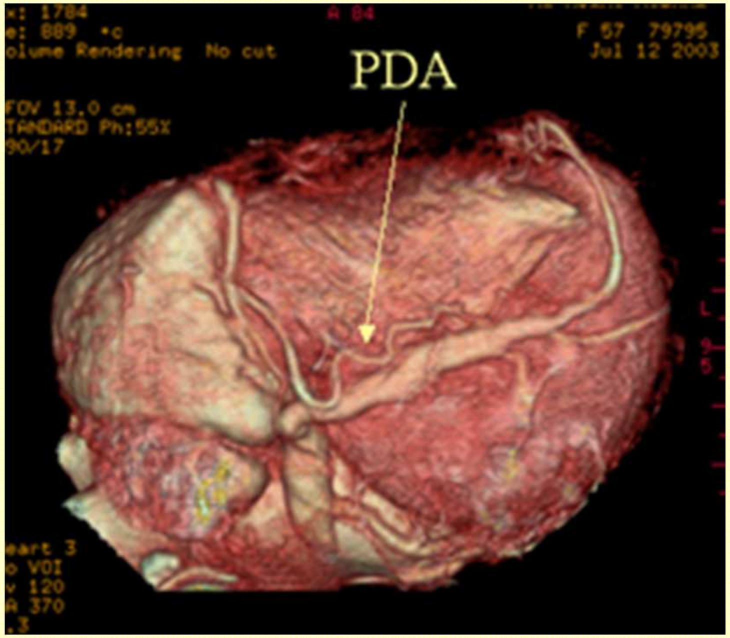


VRT for Radiotherapy

- Multiple structures and different tissue interfaces can be simultaneously visualized
- 3D treatment planning
- Superimposition of plans
- Its relationship with normal/ functionally important structures
- Display of planed target as well as skin

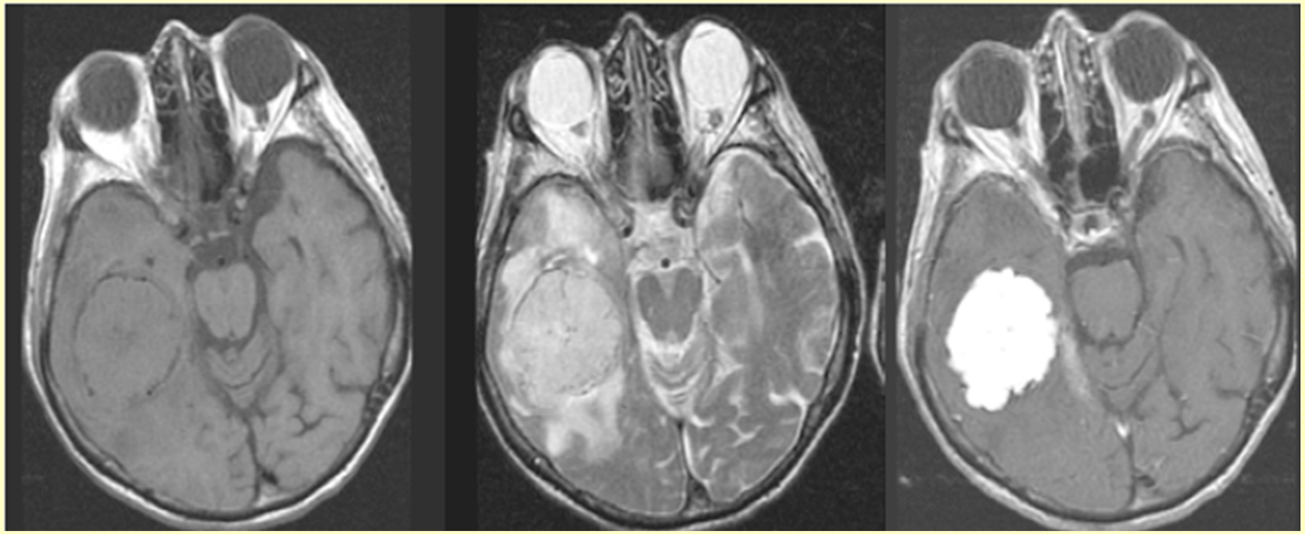
Prerequisite for Good 3D

- Thin, high resolution, overlapping slices
- Powerful workstation and software
- Possible with modern Multi-detector CT



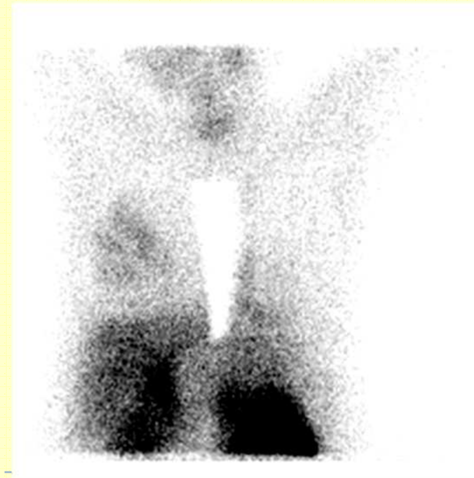
MRI

- Magnetic proprieties of the tissue molecules, usually hydrogen in water molecules
- No radiation
- Direct multi planner imaging
- Better soft issue contrast



Nuclear Medicine

- Functional information (tumor viability)
- Very poor demarcation
- Not suitable for radiotherapy planning
- PET is an important development
  - Accurate assessment of viability
  - Can be integrated to CT, MRI to compliment

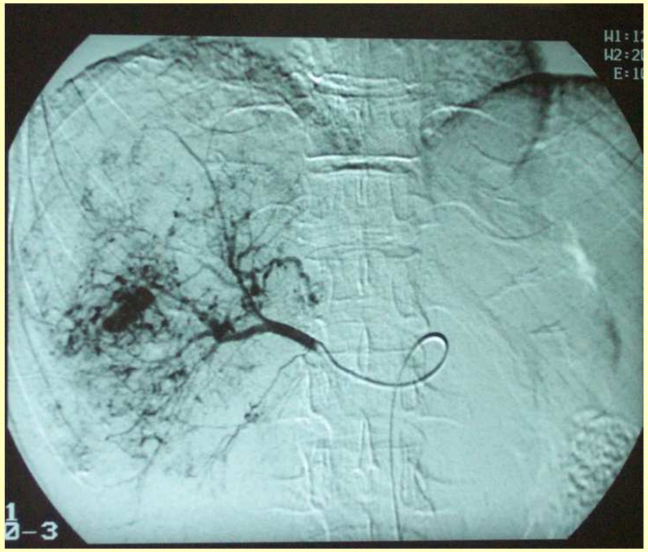


Interventional Radiology

- Percutaneous, minimally invasive image guided procedures
- Biopsy/ FNAC
  - Most body parts are accessible
  - Better instrumentations
  - Highly accurate
  - Diagnostic or staging laparotomies and thoracotomies have decreased

Interventional Radiology

- Tumor ablation
  - Radiofrequency ablation (RFA)
  - High energy focused ultrasound (HIFU)
  - Liver, bones, lung, kidney
- Chemo-embolization
  - Liver, head-neck, bones
  - Chemo-embolisation of HCC, neuro-endocrine metastases
- Radio-embolization
  - Rhenium, Yittrium



Interventional Radiology

- Palliation and supportive
- Catheter drainage
  - Abscess, effusion
  - PTBD, nephrostomy, gastrostomy
  - Can be used for brachitherapy
- Recanalisation & stenting
  - Airway, GI tract, biliary
- Pain management
  - Neurolysis
  - Vertebroplasty

Resolution of Imaging Modality

- Spatial resolution
  - Ability to differentiate and identify two closely spaced structures
  - Directly determines delineation
- Unit: line pairs per mm
  - Mammography 20 lp/mm
  - CT 2-3 lp/mm

Resolution of Imaging Modality

- Temporal resolution
  - Ability to differentiate and update two closely occurring events
  - Important for interventional procedures, functional assessment (heart, vessels, respiration)
  - In radiotherapy, crucial for brachitherapy and dynamic image guided radiotherapy (IGRT)
- Unit: frames or slices per second
- Modalities with high temporal resolution
  - Ultrasound, fluoroscopy (up to 40/ seconds)
  - MDCT and MRI (up to 10/ second)
- Spatial and temporal resolutions are usually inversely related

Functional Imaging

- Nuclear medicine
  - SPECT, PET
- MRI
  - Spectroscopy, BOLD, Diffusion/ perfusion
- Uses in Radiotherapy
  - Viability of tumor
  - Differentiation of tumor from necrosis , surrounding inflammation and edema

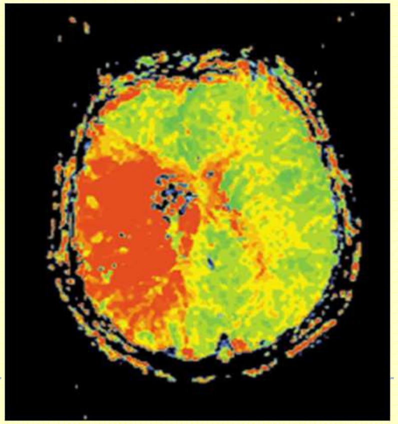


Image Fusion

- Images from two modalities superimposed and fused
  - Two complimentary modalities
  - Same modality at various time/ patient to atlas
- Integrates information from various modalities
  - Display of bones/ fiducials (CT)
  - Improved delineation of margins and tissue planes (MRI)
  - Depiction of viable part of the tumor (PET)

Image Fusion

- Difficult, far from ideal
  - Exact replication of scanning parameters for two different modalities is not possible
- Prospective
  - Controlled scan geometry
  - Use of fiducials (markers/ frames)
- Retrospective
  - Subjective/ Quantitative
  - Matching of landmarks, curves or surfaces
  - Re-slicing of second image data set along the planes of first imaging data set

Post processing for Fusion

- Color wash superimposition
- Composite image

Steps in radiotherapy

- Orthogonal x-ray/CT for initial reference
- Fluoroscopic simulation to correlate beam geometry with anatomic structures
- CT/MR with patient immobilization and markers to define target volume, vital structures
- Dose prescription and set of RT fields designing
- 3D visualization of tumor fields and anatomy: BEV
- Verification simulation or DRR for reference image
- Portal imaging by treatment machine and comparison with reference images for set up accuracy

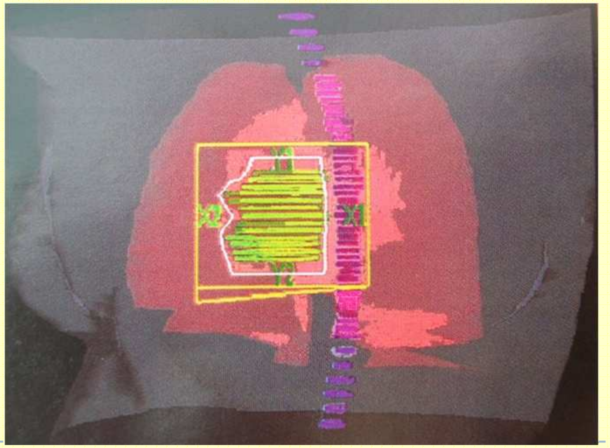
Image management

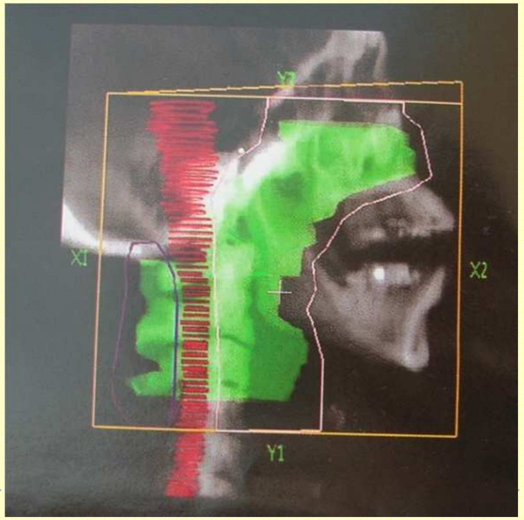
- Large number of 2D and 3D images are generated at every step
- Manual management and analysis is cumbersome

- Management
  - Use of servers and networks (LAN, WAN, Net)
  - Security and access concerns
  - Uniform digital format (DICOM-RT)

Automated image analysis

- Volume identification
- Indentify anatomic structures and planes
- Identification of spinal cord, lungs
- Auto window level and range setting
- Identification of external contour and markers
- Image fusion





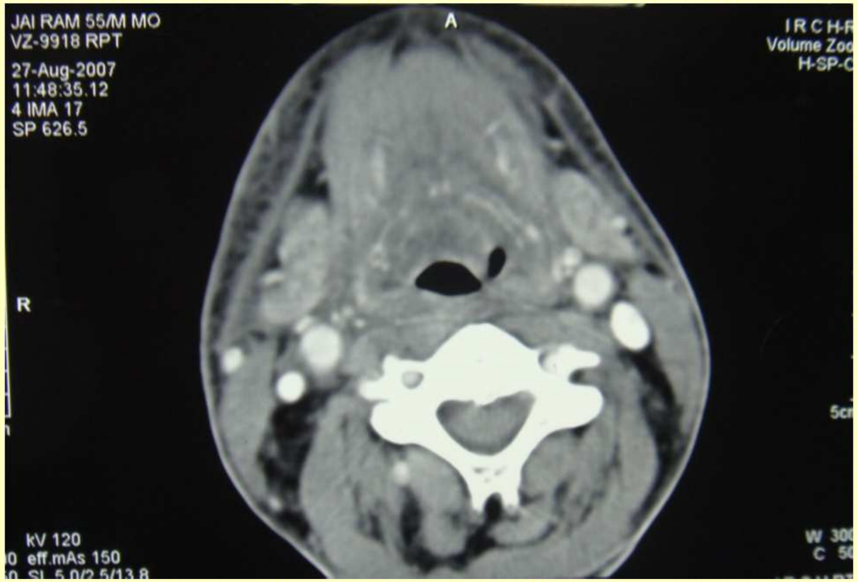
Post Treatment Imaging

- To assess response to treatment
- To monitor treatment complications
- Follow-up

- Difficulties
  - Differentiation of fibrosis from viable residual tumor
  - Post treatment changes may mimic recurrence

Post RT changes

- Thickening of skin and platysma
- Reticulation of subcutaneous fat and deep fat layer
- Increased density of fat
- Retropharyngeal oedema
- Sialadenitis
- Atrophy of lymphatic tissue

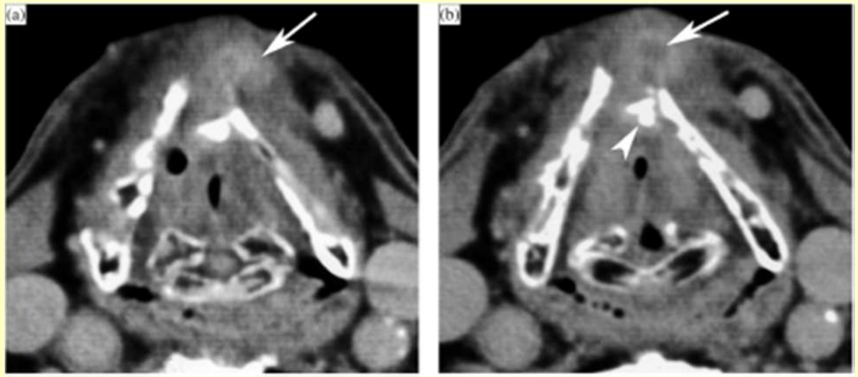


Post RT complications

- Osteo-radionecrosis
- Laryngeal necrosis
- Fibrosis induced laryngeal dysfunctions
- Radiation myelopathy
- Radiation pneumonitis
- Radiation enteritis
- Infection
- Fistula formation
- 2nd malignancy

Post RT complications

LARYNGEAL NECROSIS



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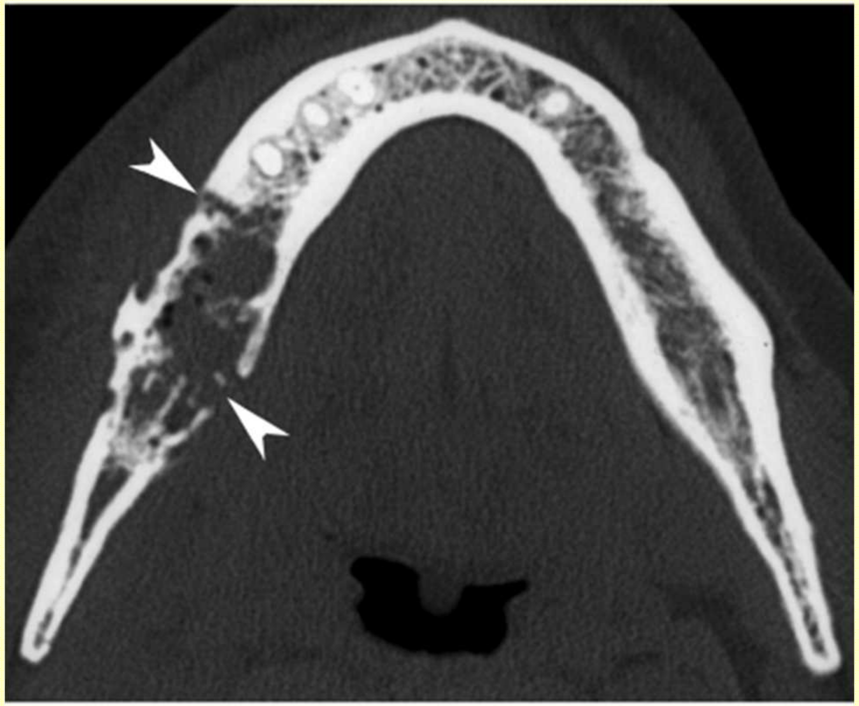
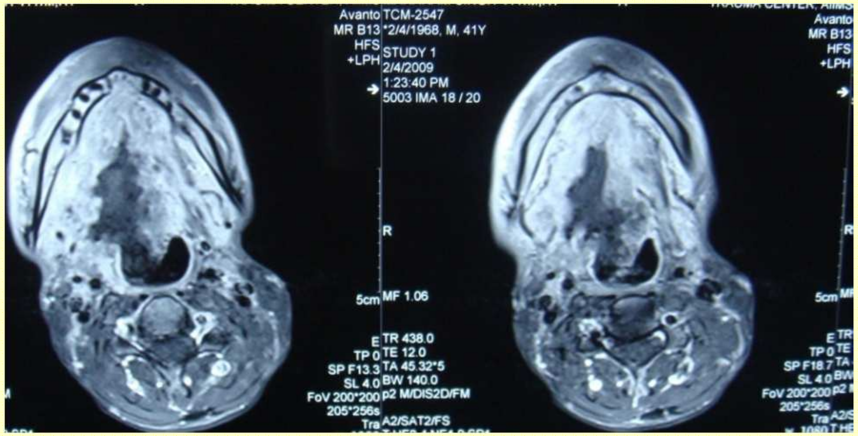


Post RT complications

POST RT ABSCESS

OROCUTANEOUS FISTULA

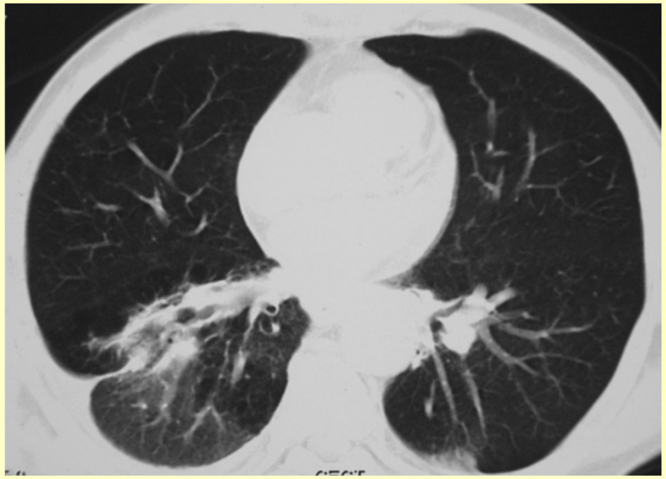


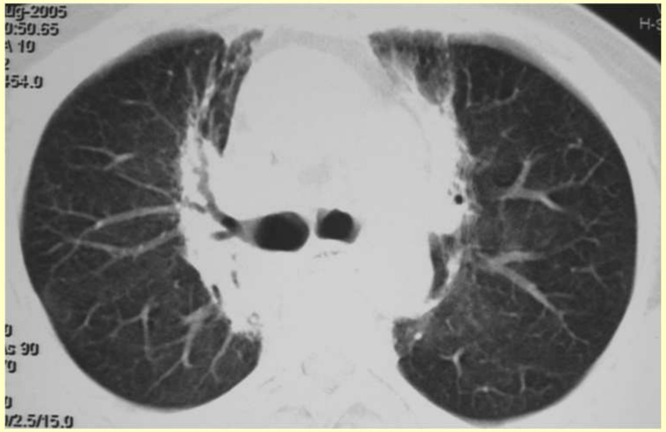
Radiation Enteritis

- Thickening of lbowel folds
- Mucosal ulcerations
- 'Ribbon' or toothpaste bowel
- Stenosis, adhesion and/ or fistula

RT pneumonitis

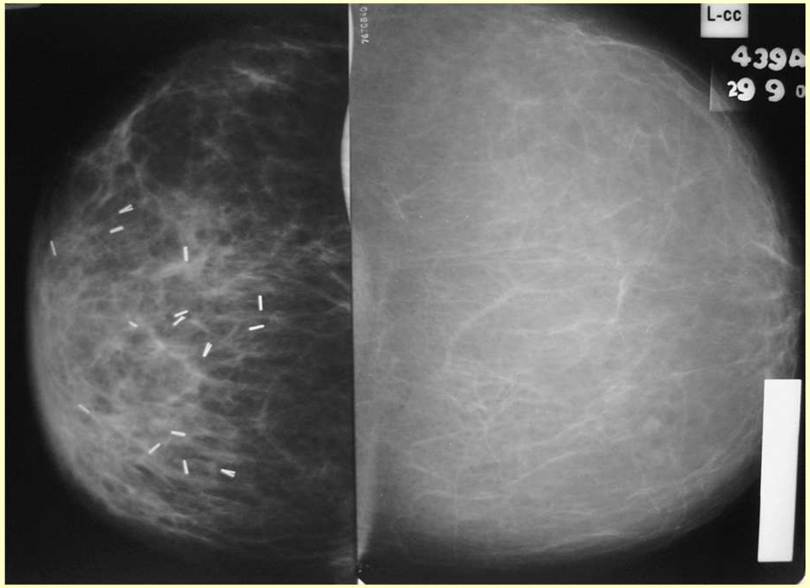
- Acute (up to 3 months)
  - Ground glass opacities with ill defined nodule
  - Confirm to RT field, sharp margins
  - 3D conformal RT: Mass like consolidation
- Chronic
  - Develops by 6-12 months
  - Stabilizes by 2 years
  - Fibrosis





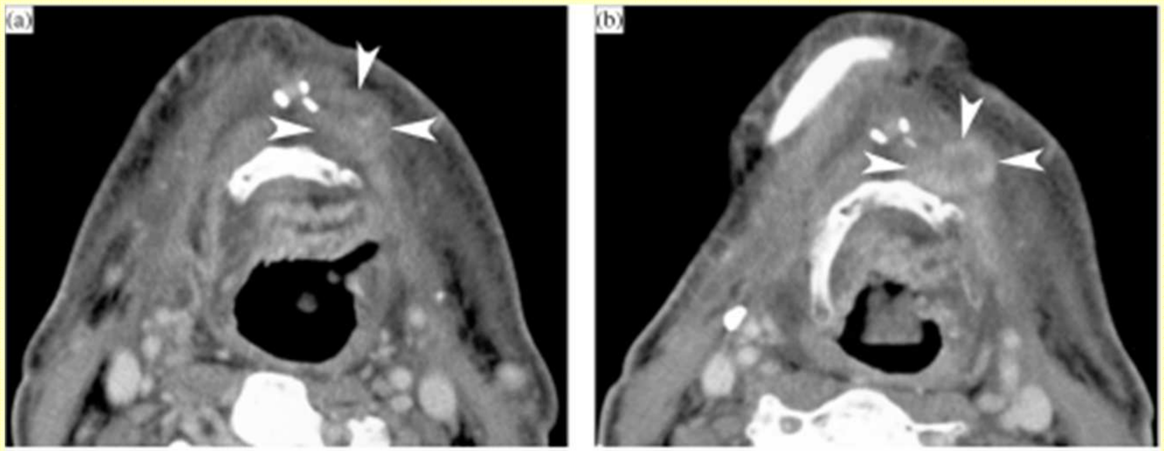
Post RT Breast

- Diffuse increased density of breast
- Benign dystrophic calcifications



Recurrence

- Early changes difficult to distinguish from changes induced by RT
  - soft tissue mass at primary site and /or as enlarged nodes
- Post RT imaging should be deferred for 6 weeks at least



Conclusion

- Tumor imaging is an essential component to develop an optimal treatment plan
  - Multimodality imaging has improved the accuracy and efficacy of planning, delivery and verification of radiotherapy
- Imaging is also required to assess response to the treatment and to monitor complications

Thank You