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Original Article

What all about most modern radiotherapy for cancer patients that is called Image guided radiotherapy and why it is so difficult in Indian context to apply this technology?

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Abstract

Traditional Radiotherapy basically use of anatomical surface landmark as well as its radiological correlation with the help of X ray imaging is basically known as 2-D planning, but in modern era of radiotherapy planning IGRT has its impactful role in radiotherapy like IGRT full benefits exploited when large organ motions and setup errors likely to occurs, All patients treated with conformal radiotherapy IGRT/SBRT should be theoretically get benefited, Clinical situations where low dose radiotherapy requires for tumor control or palliative radiotherapy or for superficial tumors are likely to get least benefit by IGRT treatment. Major concerns with IGRT are given below.

1-Limited availability of experience staff is a major concern.

2- In terms of quality control decision whether to go with new plan or continue with original plan.

3- Daily online treatment imaging of patient before treatment makes unnecessary radiation exposure is a threat for development of second malignancy.

4-Solutions for point number 3 ionizing radiation exposure is now being solved with the development of MR-LINAC.

Keywords: *IGRT, IGRT Major concerns, IGRT benefits.*

Introduction

Actually speaking imaging has a vital role to play imaging is of two types in context to radiotherapy planning

A- Highly sophisticated imaging techniques

B- In room imaging methods.

Sophisticated imaging techniques Are CECT, MRI, PET Scans they obtain 3D images of target volume as well as biological information of target volume of tumor thus it enables precise and accurate treatment planning with beam shaping in Isocentric or Non Isocentric geometry to get target volume better coverage .

In room imaging techniques–

This very technique helps in obtaining target volume position as well as its moment during treatment and in between the treatment called as intrafractional or interfractional respectively, we above images with reference images and apply method to correct the target volume and patient set up in order to get optimize target localization this also help to provide feedback that may help to adopt subsequent treatment fractions according to the tumor response that is called Adoptive radiotherapy.

So in room imaging application called as image guided radiotherapy

Modern external beam radiotherapy techniques such as IMRT, VMAT that is volumetric modulated Arc therapy, SRS, SRT have helped to reduce normal tissue radiation dose without compromising radiation delivery of tumorocidal dose to target volume.

However there is a great deal of uncertainty in defining the position of target during the radiotherapy as well as between the two fractions of radiotherapy.

Target may move during the treatment due to respiratory breathing, peristaltic moments of bowel, cardiac pulsations, urinary bladder and rectal filling may lead moment of prostatic tumors hence we need to develop strategies to measure, monitor and correct these uncertainties this leads to evolution of various in room imaging technologies which enable to correct setup errors, anatomical changes related to weight loss or moment of internal organs.

In Brachytherapy treatment planning also incorporate orthogonal X ray imaging for guiding brachytherapy catheters and its applicators placements and volumetric imaging with help of CT ,MRI, for applicator identifications and its reconstructions to plan optimizations in 3d imaging, Isodose distribution is reviewed and optimized on visualization of dose distribution to target as well As critical structures .

Basic Concept of IGRT –

Traditional radiotherapy carries a disadvantage of making significant numbers of assusumption in its technique. 3D dataset acquired at simulations is basically a snapshot of tumor and its relation to normal structures well as patient anatomy and shape on a single point of time on which 3D image was taken this model is used for treatment planning and dose calculations

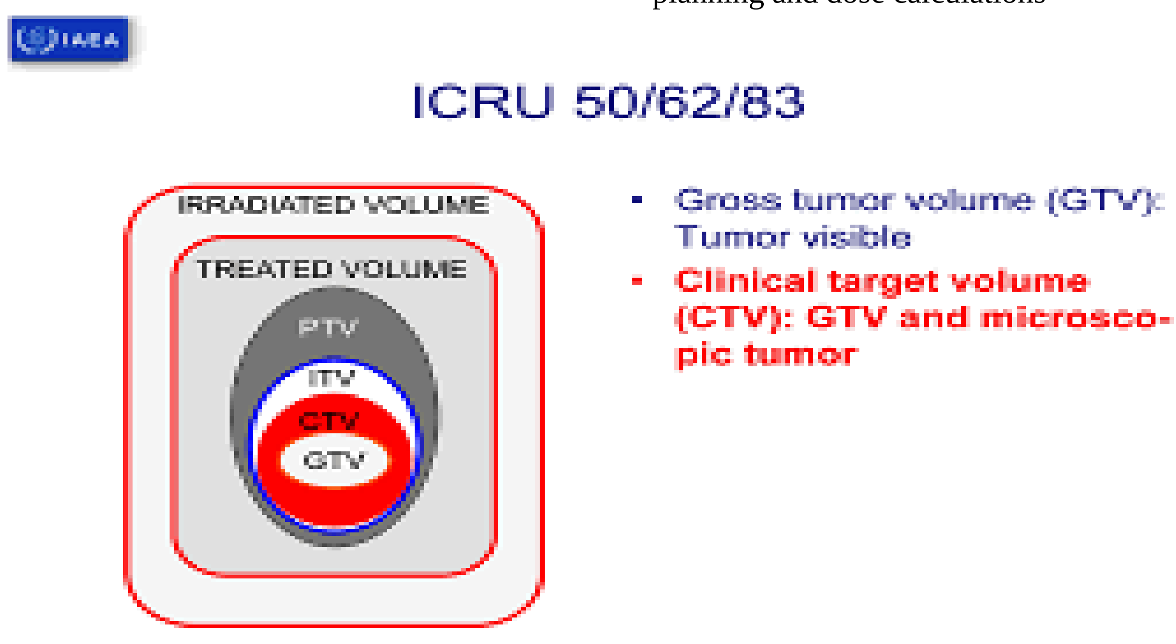

Fig-1 Defining, GTV, CTV, PTV.

Including lot of assumptions based on prior experience. and literature to finalize the CTV, PTV margins while incorporating again assumptions expend range of microscopic range of tumor to define CTV and assumption about expected range of organ motion leads to tumor motions with belief that assumptions hold true for ant given patients during daily treatment fractions of radiotherapy, however the above given assumptions of dose calculations done on CT image data set on TPS and dose delivered throughout the entire course of radiotherapy is basically a gross error, because internal organ motion like target volumes moves with respirations, peristalsis, cardiac pulsations, patient weight loss target, bladder and rectal filling leads to the changes in target volume delineations as well as large volume of normal tissue, Delineations as well as large volume of normal tissue.

IGRT gives a method to capture this information regularly during treatment course in form of serial snap shots of CT images is a means of verifying accurate and precise radiation delivery in terms of IGRT process ensures that delivery treatment matches the intending in accurately targeting the tumor while minimizing the collateral damage.

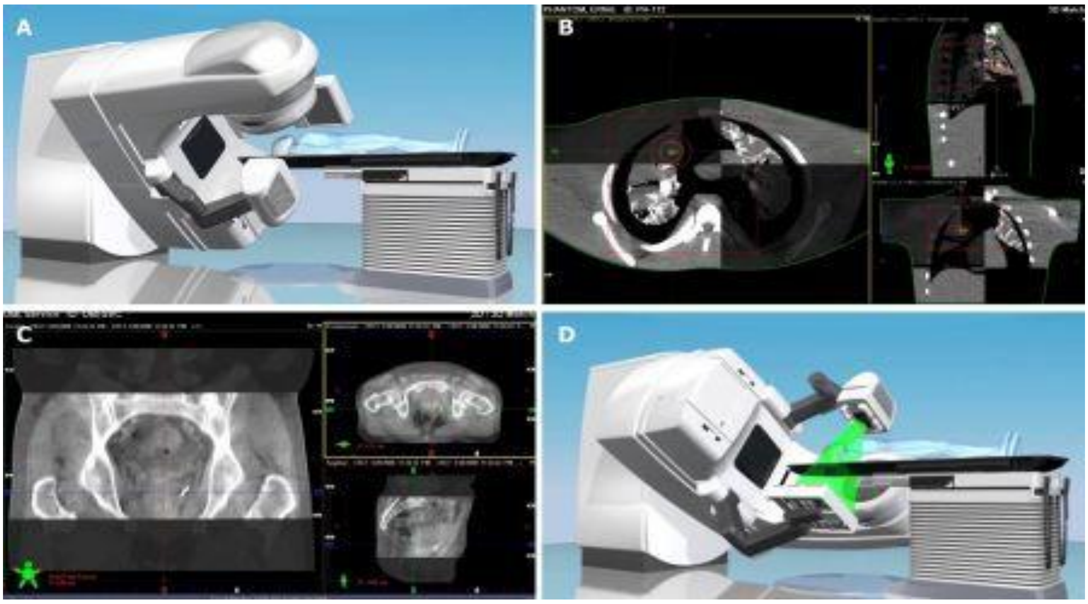

Figure -2 CT Imaging Fully Utilize in Radiotherapy Planning.

Delivery dose may be minimize by use of appropriate localization devices and PTV margins occasionally re planning may be required if gross deviation found during counter check imaging beyond predetermined target volumes or margins .

IGRT allows assessment of geometric accuracy of the patient model during treatment delivery it provides methods where by deviations of anatomy from initial plan are determined and its information are used to update dose assumptions , the corrections strategies may includes daily repositioning to register patients positions in accordance to base plan or recalculation of treatment delivery in real time in order to reflect patient presentation during a given fractionations .

The philosophy of evaluating the treatment planning accounting the difference between actual patient anatomy on a given day and the snapshot of planned treatment is known as **Adaptive Radiotherapy**.

The final objective is to reevaluate in certain situations redefine daily positioning for radiotherapy treatment to keep on the same track as predefined and intended treatment plan of radiotherapy.

Technologies and Solutions for Corrections of Margins and Errors

An error in radiotherapy delivery is defined as any deviation from intended planned treatment planning; a great degree of uncertainties is inherent to radiotherapy practice and may be in form of

1- Mechanical uncertainties related to treatment unit (machine) parameters such as couch and gantry motions.

2- Patient uncertainties – related to ability to lie comfortably in certain anatomical positions and cooperate during treatment delivery

3- Geometric uncertainties- related to position and motion of target volume which may occur during radiotherapy intra fractional or inter fractional both uncertainties may be a result of combination of systemic errors and random error

Systemic Error- is basically a treatment planning error and is introduce into chain during process of CT simulation, patient positioning, target delineation (contouring of tumor), these errors if not corrected would affect all treatment fractionations uniformly , thus it's very important correct the systemic error from the very beginning of the treatment planning .

Random Error– Other hand random error is basically treatment execution error which is unpredictable and varies with each fraction.

Systemic error shifts entire dose distribution away from CTV thus systemic error is more dangerous because it would affect much larger impact on treatment accuracy henceforth therapeutic ratio as well.

Margins are added to CTV to take up these errors into account, these margins are geometric expansions around the CTV and may be non uniform in its all the dimensions depending upon expected errors these margins ensures that target volume and planning goals are met despite the variations during as well as in between the fractions of radiotherapy .

ICRU 62 (1999) defines expansions of PTV around CTV as composite of two factors Internal Margin that is target motions and Set Up margins that is day to day patient set up variations ,Depending upon observed systemic and random errors in a given setup for particular treatment site a verities of advice given in literature to correct these PTV margins, but to enhance the therapeutic ratio a host of correction strategies may be applied to reduce marines errors that include online correction or offline correction or real time corrections of intra fractional motions , tracking and correcting organ motions help to reduce internal margins while improving in the accuracy of positioning which directly help to reduce setup margin henceforth reducing the un required PTV margins .

Offline and Online Correction Streatgies -

Online correction strategies refer to weather corrections done when patient is on treatment couch and its verification done is called online correction. But when this correction is being done for subsequent fractions this will be called as offline correction.

Offline Correction- In the offline correction strategies images are acquired before the treatment and matching is being done with the reference images at later point of time this strategies aims to determine the individual systemic error thus reduced it , when this compared with setup data of another patient treated under same protocol it helps in defining the population standard error for that type of treatment in that institution .

Online Correction– online correction strategies on other hand employs acquisition of images and their verification and correction just prior to on that very day treatment ,henceforth it reduce both random and systemic error both .the treatment site and expected magnitude of error may determine the frequency of imaging used for online correction.

Sites where large daily shifts are anticipated for example thorax, abdominal , and pelvic tumors in mentioned site even small shift will alter the dose distribution within adjacent critical structures example Para spinal tumors , intracranial tumors in close proximity to Optic Chiasma are best managed with daily imaging , data of online corrections shows that maximum errors occurs in thorax followed by abdominal errors and pelvic tumors and minimum errors where observed in head and neck region .

The treatments of radiotherapy such as VMAT, SBRT carry potential to translate minor shift to major alterations in dose distributions in dose distributions henceforth these kind of treatment requires daily online imaging and its verifications for daily online corrections for both systemic as well as random error both error can be calculated with match data , the post treatment imaging is required to quantify both intra fraction motions and residual errors if evaluated for population these data may help to check PTV margins for that very protocol use for daily online imaging has eliminated the need of invasive form of SRS Radiotherapy treatment.

IGRT Imaging Technologies and Its Solutions-

Imaging methods used in IGRT treatment has been divided in two categories

A- Non Radiation Based Imaging Systems

B- Radiation Based Imaging Systems

Non Radiation Based Imaging Systems –

1- USG Based Systems
2- Infrared Camera Based Tracking System
3- Electromagnatic Based Tracking System
4- MRI Based Imaging System.

Radiation Based Imaging Systems –

1- EPID Based Imaging
2- Cone Beam CT Based
3- Fan Beam KV Based CT / CT On Rails
4- Fan Beam MV Based CT / Tomotherapy
5- Real Time 4D Traking / Cyber Knife
6- Real Time Tumor Tracking System.

Non Radiation Based Imaging Systems-

USG Based System - This system acquire 3D Images that help to align target to correct intra fractional errors this can be used for Prostate, and Lung tumors.

Figure-3 USG Based System Used For IGRT Treatment

Infrared Camera Based Tracking System

These system identifies the patient reference setup point position in compression to planned CT setup point which aids during treatment delivery to align the treatment Isocenter with already planned CT imaging Isocenter, this infrared camera based imaging system may also be used for intra fractional position monitoring for Gating means treatment delivery on only when moving tumor falls under the set position of Gate or used for repositioning correction , this systems used in treatment of prostate ,breast tumors and respiratory gating use external surrogates, external surface may act as reliable surrogates for internal organ motions under limited situations where external surrogate can be used or consider as reliable method of choice.

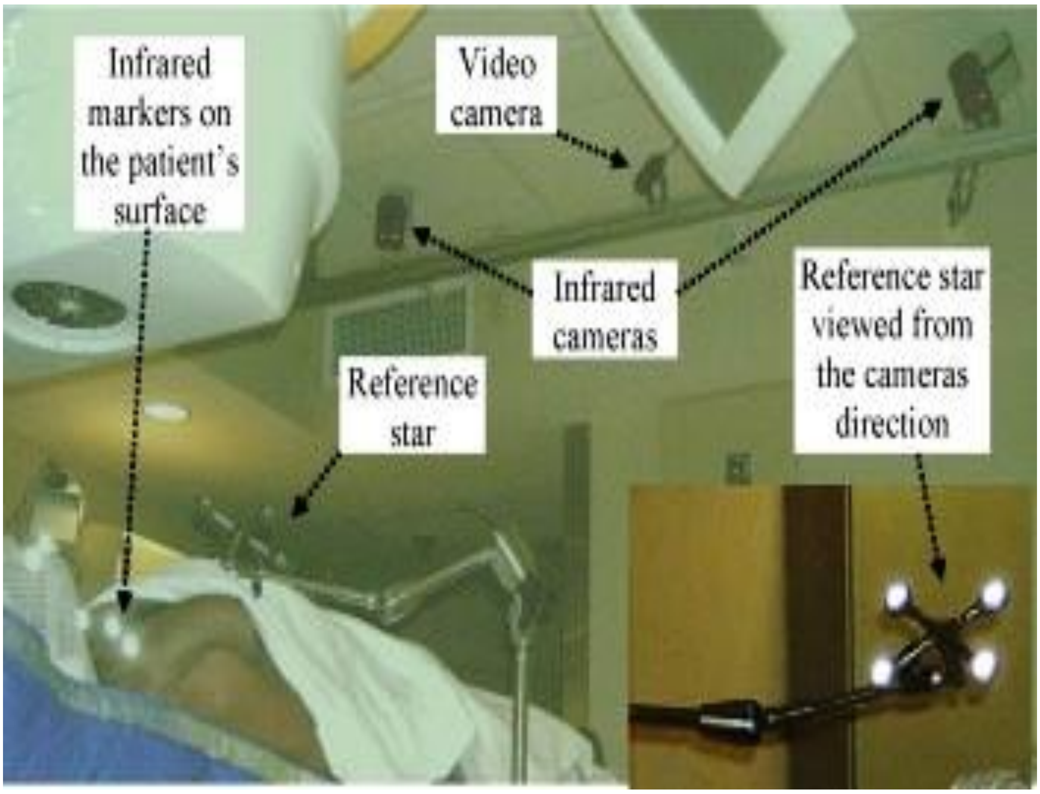

Figure-4 Infra Red Camera Based Tracking System Used in IGRT

Electromagnatic Image Tracking System /Calypso-

This system make use of electromagnetic transponders called BECONS embedded within the tumor , motions of these BECONS may be tracked by using detector system ,BECONS need to be placed in tumor via minimal invasive procedure, but their presence produce artifacts in MR images at present this system use is limited up to prostate cancer.

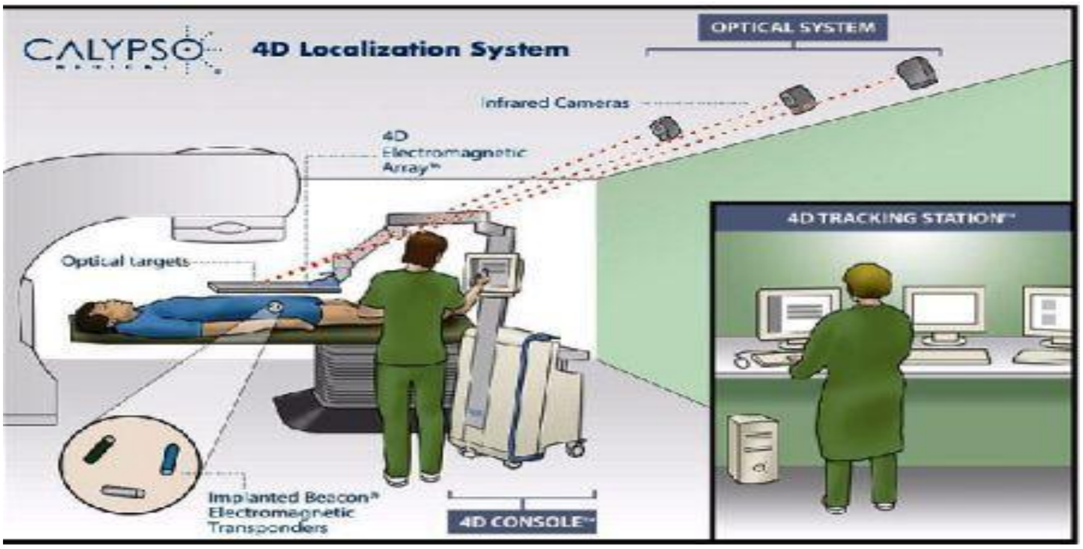

Figure -5 Calyspo Becons Used in IGRT

MRI Based IGRT System

Real time assessment of internal soft tissue anatomy and motions by using continues soft tissue imaging by MRI allows intra fractional correction, however this system has limitations such as motion artifacts cannot be performed in patients with pacemakers or metallic implants

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Radiation Based Imaging Systems Used in IGRT

A- Electronic Portal Imaging Devices –

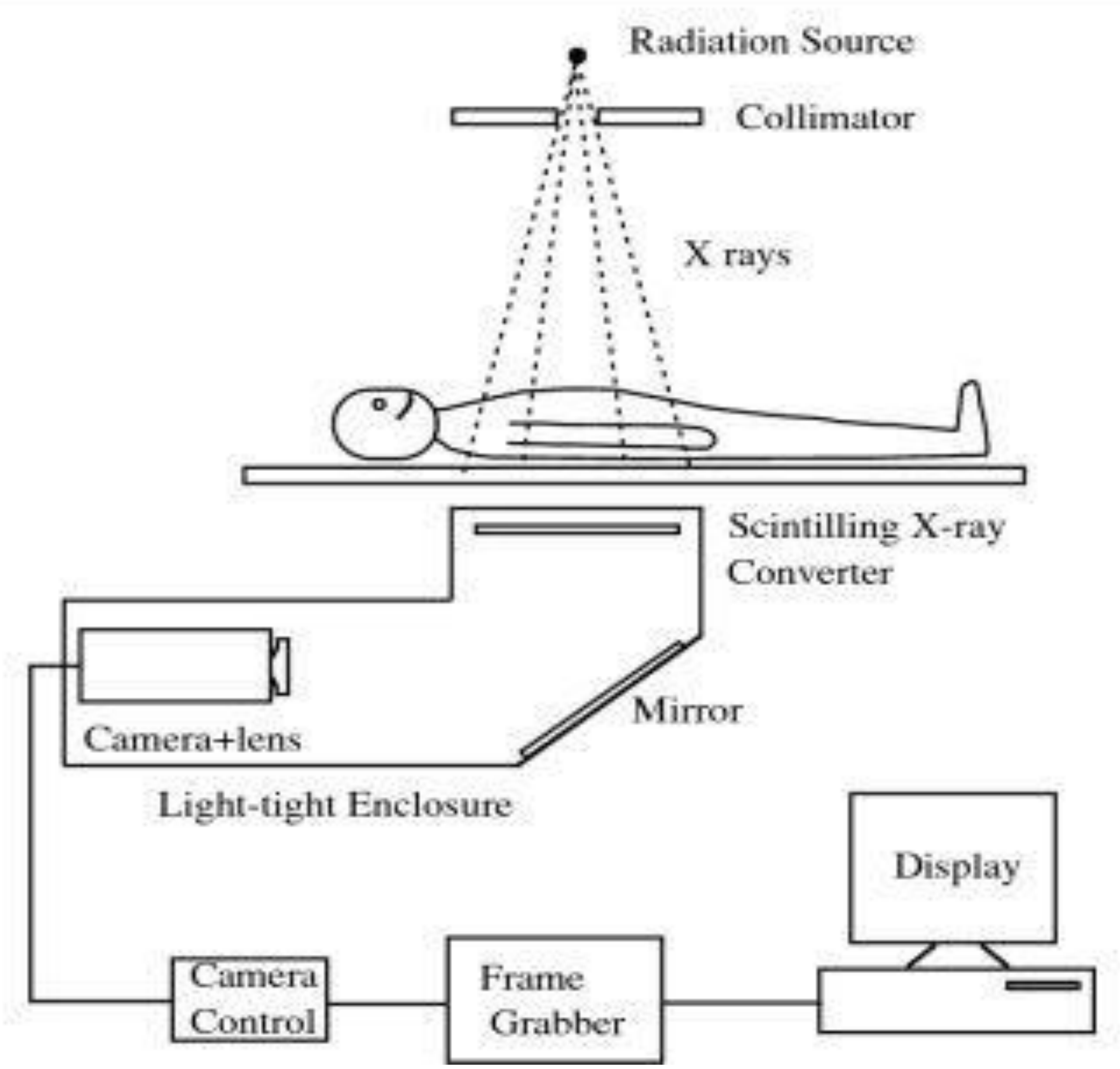

Figure-6 How Image Matching and Dose Calculation done on Machine It Self

EPID was developed as replacement of film dosimetry for treatment field verifications, EPID based on detection of active flat panel images AMFPI, they offered as slandered in built equipment usually in all modern Linear Accelerators machines, EPID acquires 2D images, boney landmarks, planner images are used as surrogates (markers) for defining positional verifications in reference to digitally reconstructed radiographs DRR which usually we get by the help of CT planning data set.

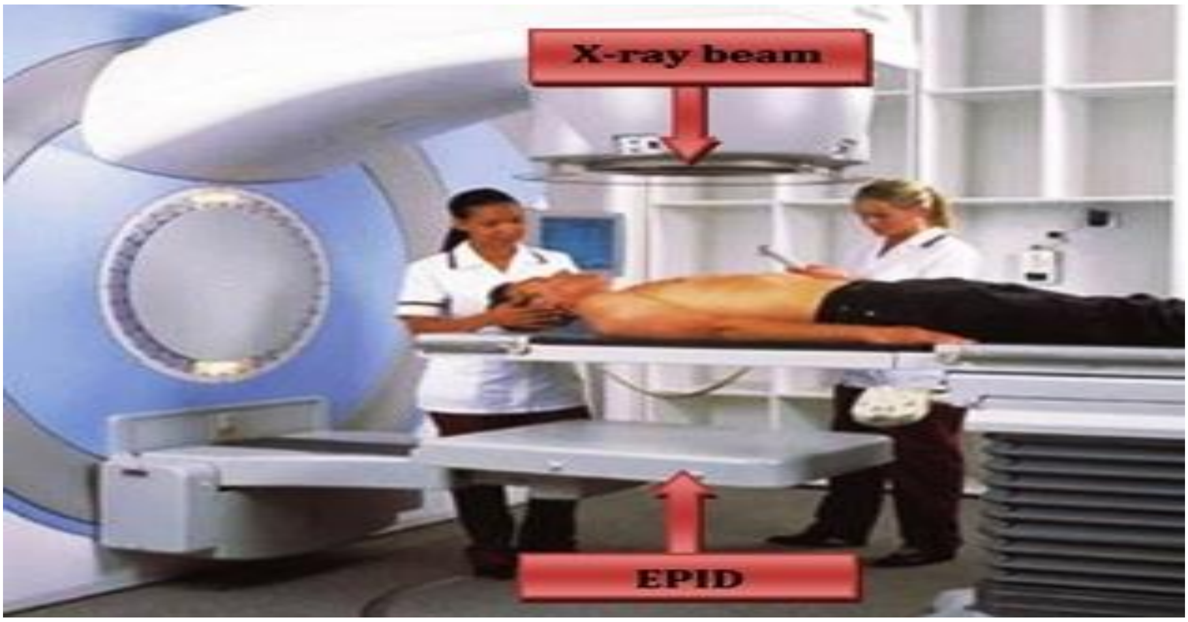

Figure -7 Epids Role in Image Capturing as well as Dose Calculation

EPID system may use KV imaging or MV imaging ,images contrast seen better with KV imaging also KV imaging produce images with lesser distortion from metallic implants like dental implants or hip prosthesis which commonly seen with megavoltage MV imaging ,Only limitations of EPID SYSTEM that ey cannot detect or quantify rotation.

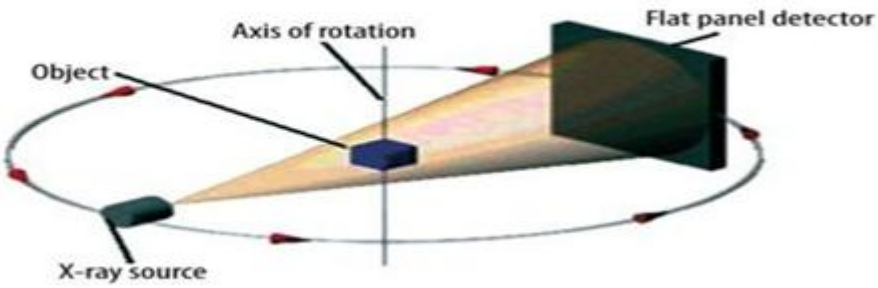

Figure -8 Cone Beam CT

These system clubbed with linear accelerator along its treatment axis by help of cone beam CT volumetric images are generated which can be compared with planning data set for corrections in cone beam CT gantry rotation around couch acquiring the average position of target organ with respiratory motion both inter fraction set up changes and anatomical changes related to weight loss of patient after few fractions of radiotherapy or organ fillings urinary bladder / rectal filling may be monitored , Repeat scanning of at the end of treatment may give an estimate of intra fractional changes , this system also help in treatment response evaluation and these scans may be use for recalculation of dose or treatment plan revision .

FAN Beam CT (CT –ON RAIL) –

This system has in room ct scanner its gantry moves along treatment couch , 3D images are taken with patient immobilized on couch , its different from diagnostic ct because fan beam ct scanner having wide bore aperture more than 80 cm to accommodate bulk immobilizations' devises, diagnostic CT scan usually having aperture of 70 cm only.

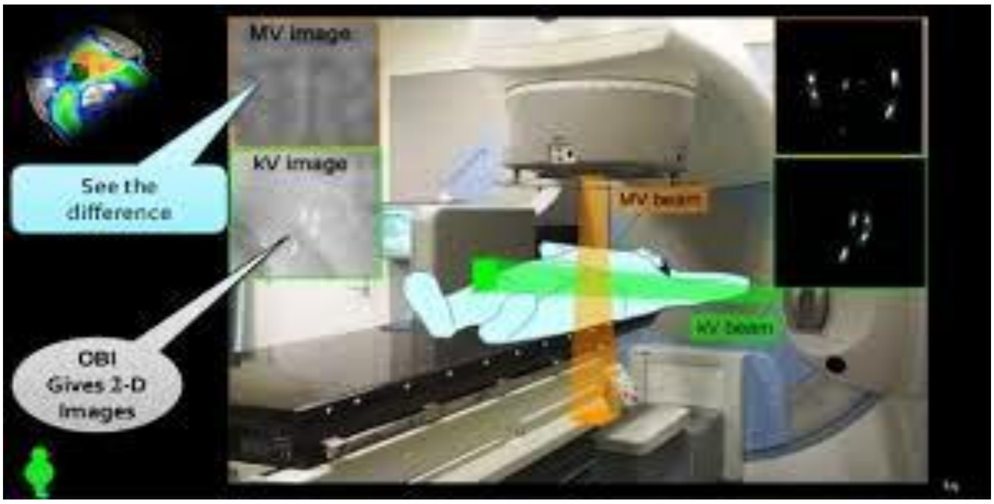

Figure -9 Imaging Use Treatment Machine Either by Kilovoltage or Megavoltage Beam.

B- Fan Beam MV CT (Tomotherapy) -

This system includes an onboard imaging system to obtain mega voltage ct images of the patient In treatment position on the couch the same linac here use to generate 6MV for treatment and 3.5 MV for imaging purpose.

Real Time 4D Tracking (Cyber Knife)-

Figure -11 Cyberknif System Work Flow Diagramatic Picture.

Cyber Knife system consists of a compact linac mounted on a robotic manipulator arm which directs the radiation beams to desired target volume based on inputs from two orthogonal X-ray imaging system mounted on the room ceiling with flat panel at floor as floor detectors on either side of couch which helps to provide image guidance during treatment process , images are acquired throughout the treatment duration (that's why called real time tracking) and couch and robotic head movements are guided through an automatic process several tracking methods may be used depending upon the tumor treatment site .

Fiducial Markers- May need to placed within tumor target and tumor motion is tracked and corrected for monitoring the fiducial marker position including translational rotations and deformation (tumor shrinkage), Respiratory motion is also monitors and accounted for correcting the target position and motion through a synchrony model generated in real time imaging minor invasive procedure are required if fidicual markers are needed for tracking , this system may be used for both cranial (frame less) and extra cranial radio surgery / SRS /SRT.

What Is All About Real Time Tumor Tracking System??

This system designed for real time tumor tracking by help of imaging of implanted fiducial markers and using this information for gating , it basically consist of four X-ray camera system mounted on floor, and ceiling mounted image intensifier (just reversed or opposite to cyber knife system). The linac head for beam is gated to irradiate the tumor only when the implanted marker in the tumor lies or falls in the planned treatment field.

IGRT Technology Implantation –

Fiducial Markers– These serve as surrogates to soft tissue targets when they are difficult to visualize and their alignment cannot be related to boney land marks, these markers may be tracked in real time to obtain 3D coordinates for target corrections.

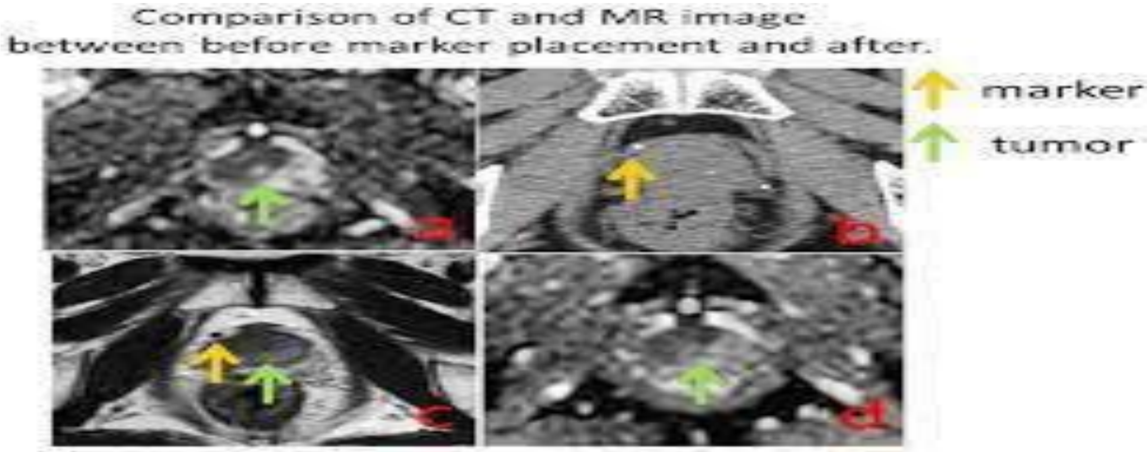

Figure -12 Fiducial Markers Used In Image Varifications

Figure -13 Fiducial Markers Implantation

Moving Target Volume Delineations – Intra fractional target volume motion or Inter fractional target volume motion /displacements, deformation (change in shape of target volume), or alteration of target should be accounted during determinations of PTV, these process start from simulation scratch up to the end of radiotherapy treatment .

Patient Positioning– Ensure the accuracy of patient positioning and its daily reproducibility for fractionated treatment in reference to the chosen IGRT device as well as Radiotherapy treatment unit type of Machine.

Image Acquisition – System should be calibrated to ensure high quality imaging with attention to slice thickness uniformity , image contrast resolution , Isocenter alignment between treatment planning and delivery system also ensure accuracy of soft were used and correction of couch misalignment .

Treatment Verification– Image review by radiation oncologist at first fraction and then periodically as well as is necessary to ensure treatment accuracy and its reproducibility record of periodic verification must be maintained this would help to determine department thresholds for required correction as well as its dataset serve as guide for modification the process involved for subsequent same site radiotherapy planning for different patient.

References

1. Reco C, Clifton Ling C. Broadening the scope of image-guided radiotherapy (IGRT). Acta Oncol 2008;47:1193-200.
2. Verellen D, Ridder MD, Storme G. A (short) history of image-guided radiotherapy. Radiother Oncol 2008;86:4-13.
3. Bernier J, Hall EJ, Giaccia A. Radiation oncology: A century of achievements. Nat Rev Cancer 2004;4:737-47.
4. Intensity Modulated Radiation Therapy Collaborative Working Group. Intensity-modulated radiotherapy: Current status and issues of interest. Int J Radiat Oncol Biol Phys 2001;51:880-914.
5. Dawson LA, Jaffray DA. Advances in image-guided radiation therapy. J Clin Oncol 2007;25:938-46.
6. Van Herk M. Different styles of image-guided radiotherapy. Semin Radiat Oncol 2007;17:258-67.
7. Korreman S, Rasch C, McNair H, Verellen D, Oelfke U, Maingon P, et al. 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. Radiother Oncol 2010;94:129-44.
8. Michalski J, Purdy JA, Gaspar L, Souhami L, Ballow M, Bradley J, et al. Radiation Therapy Oncology Group. Research Plan 2002-2006. Image-Guided Radiation Therapy Committee. Int J Radiat Oncol Biol Phys 2001;51:60-5.
9. Van Herk M. Errors and margins in radiotherapy. Semin Radiat Oncol 2004;14:52-64.
10. Verellen D, De Ridder M, Tournel K, Duchateau M, Reynders T, Gevaert T, et al. An overview of volumetric imaging technologies and their quality assurance for IGRT. Acta Oncol 2008;47:1271-8.
11. Baumann M, Hölscher T, Zips D. The future of IGRT - cost benefit analysis. Acta Oncol 2008;47:1188-92.
12. Dawson LA, Sharpe MB. Image-guided radiotherapy: Rationale, benefits, and limitations. Lancet Oncol 2006;7:848-58.
13. Van Herk M, Barrilot I, Bel A, Bijhold J, Bruce A, de Jaeger K et al. Geometric uncertainties in conformal radiotherapy-and how to deal with them. Brussels: Proceedings of the 6th International Workshop on Electronic Portal Imaging; 2000. p. 5-7.
14. Simpson DR, Lawson JD, Nath SK, Rose BS, Mundt AJ, Mell LK. A survey of image-guided radiation therapy use in the United States. Cancer 2010;116:3953-60.