An Introduction to the Intensity Modulated Radiation Therapy (IMRT) Techniques, Tomotherapy and VMAT

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Abstract:

The goal of radiation therapy is to administer a therapeutic dose of radiation to a target while limiting the side effects caused by delivering dose to surrounding tissues and vital organs. The ongoing pursuit to achieve an optimal dose distribution has prompted the radiation therapy profession to develop new techniques that incorporate advances in technology. In radiation therapy today, modern techniques that include three dimensional conformal radiation therapy (3DCRT) and intensity modulated radiation therapy (IMRT) are routinely used in the treatment of cancers. Compared to 3DCRT, IMRT is capable of producing dose distributions that conform to the planning treatment volume (PTV) and deliver a reduced dose to surrounding tissues and vital organs. This has come with the cost of increased treatment time and larger volume of normal tissue receiving low radiation doses. Most recently, there has been considerable interest in the rotating gantry IMRT techniques, tomotherapy and volumetric modulated arc therapy (VMAT). Tomotherapy is a dedicated treatment system that is best described as a combination of a CT scanner and a linear accelerator. In tomotherapy, treatment is delivered using a rotating fan beam. A therapeutic dose is delivered when a patient is translated smoothly through the bore of the machine as its gantry continuously rotates. Tomotherapy is capable of producing high quality plans that increasingly spare dose to surrounding organs at risk. In VMAT, treatment is delivered using a cone beam that rotates around the patient. The cone beam is modulated by dynamic MLC, variable dose rate, and variable gantry speed to generate IMRT-quality dose distributions in a single optimized arc around the patient. VMAT treatments can significantly reduce the time and monitor units required to deliver a patient's treatment. Conventional IMRT, tomotherapy and VMAT typically produce dose distributions of similar quality. Which technique is most suited to treat a patient will depend on considerations such as the availability of the specific treatment type and its impact on the utilization of departmental planning and treatment resources.

Introduction:

Within one year of Roentgen's discovery of X-rays in 1895, radiation was being used for the treatment of various malignant diseases [1].

From the 1950s to the late 1980s the approach to radiation therapy was largely a two-dimensional (2D) approach. In 2D radiation therapy:

- Image acquisition relied on the use of a conventional x-ray simulator to generate planar radiographs on which bony anatomy landmarks could be visualized and used as cues for volumes of interest,

- Plans were created on a limited range of images and standardized beam arrangement techniques were used [2], and

- On treatment rectangular and symmetrical collimation was used with manually applied shielding blocks collimating a beam .

The central dogma of curative intent radiation therapy had been largely realized; that is, radiation therapy aims to deliver a prescribed dose across a target volume, while keeping dose to the surrounding tissues and vital organs to a minimum. However one restriction was still the doses received to surrounding organs.

Technological advances since the early 1990s have changed the practice of radiation therapy significantly, and radiation therapy transitioned from the 2D method, to a three-dimensional (3D) highly conformal approach.

In the 3D paradigm:

- Image acquisition included imaging technologies such as computed tomography (CT), magnetic resonance imaging (MRI) and positron emission tomography (PET). These imaging modalities provide a full 3D anatomical model of the cancer patient. This permits more accurate identification of tumor volumes and their spatial relationship with other tissues [3].

- Advances in computing technology allowed treatment planning systems to incorporate these new imaging technologies to generate and calculate treatment plans in 3D.

- The multi-leaf collimator (MLC) system was developed which allows precise shaping of the treatment beam to the target volume in beams eye view (BEV).

These technological advances combined led to the development of 3D conformal radiation therapy (3DCRT). 3DCRT generally uses an increased number of fields that are shaped by MLC to conform the dose to the target volume while shielding normal tissues. Therefore in 3DCRT treatment, a more uniform dose is delivered to a 3D target volume and the dose received by the surrounding tissues and vital organs is reduced.

With 3DCRT came a review of the 2D dogma. It was now possible and easy to give the tumour high doses. Perhaps the dogma had now changed to ensuring a high and homogenous dose to the target while avoiding doses to all other structures.

The improved levels of dose conformity achieved by 3DCRT increased the chance of a geometric miss during radiation therapy treatment. The consequence of missing the target encouraged the development of improved imaging capabilities at the time of treatment. Imaging in the treatment room during a course of radiation therapy, with decisions made on the basis of the imaging, is referred to as image-guided radiation therapy (IGRT) [4]. IGRT focuses heavily on the potential benefit of advanced imaging and image registration to improve precision, thus reducing the volume of healthy tissue irradiated and potentially allowing for dose escalation [5].

Since the mid 1990s and early 2000s there has been an explosion in the development of an advanced form of radiation therapy called intensity modulated radiation therapy (IMRT). IMRT represents a major shift in the practice of modern radiation therapy [6]. Notably, IMRT can provide an improved dose distribution and increased dose homogeneity when compared to 3DCRT. IMRT itself has taken many forms including step-and-shoot IMRT, sliding window IMRT, tomotherapy, volumetric modulated arc therapy (VMAT), stereotactic body radiation therapy (SBRT), cyberknife and proton therapy. It is beyond the scope of this paper to discuss each of these IMRT technologies in detail. Instead this paper will introduce the concepts behind IMRT and the most commonly utilized techniques, step-and-shoot and sliding window IMRT. The discussion will then focus on the IMRT methods that arguably are of most interest currently, the rotating gantry IMRT techniques, tomotherapy and VMAT.

Intensity Modulated Radiation Therapy (IMRT):

IMRT is the delivery of radiation to the patient via fields that have non-uniform radiation fluence [2]. The introduction of IMRT creates the possibility of generating dramatically improved dose distributions that could be tailored to fit complex shapes.

IMRT improves on the dose distributions achieved using 3DCRT. 3DCRT beams are fashioned with tight margins to conform to a target volume. A major limitation of 3DCRT is that it is unable to account for indentations in the target where critical structures invaginate into the target volume. IMRT addresses this shortcoming of 3DCRT in that IMRT offers great flexibility in sculpting the dose to complex shaped targets [7].

The complex shapes achieved using IMRT are made possible in that IMRT considers each radiation beam as multiple rays, or beamlets, and assigns different beam strengths to the individual rays. These beamlets treat very small areas of tissue, called voxels, which are a cubic millimeter of space. The beamlets are designated to satisfy the predetermined dose specifications to the tumor site and surrounding normal tissues. By modulating both the number of treatment fields and the intensity within each field, there is a greater control of dose distribution around the target and the dose homogeneity within the target [8].

A new feature of IMRT that is not normally associated with previous planning techniques is the inverse-planning process. Both 2D conventional and 3DCRT rely on forward-planning to create radiation dose distributions. In forward-planning, after the radiation treatment fields are designated by the physician, a physicist or dosimetrist defines the number, direction, beam weighting and shapes of the radiation beams that make up the plan. Based on these decisions and inputs, a treatment plan is produced and a judgment is made on how well the plan meets the prescription.

An IMRT plan is typically created with inverse-planning (also referred to as reverse-planning). In inverse-planning, the physician will outline the target on the CT simulation images. Due to the potential of IMRT to sculpt radiation dose around and between volumes, the CT simulation data sets can be fused with PET or MRI images to more accurately define the target volume and surrounding normal structures. The treatment planner will then enter the desired dose limits for the tumor as well as the dose constraints for the surrounding normal tissues. Inverse-planning software, using a dose optimizing algorithm, determines the radiation beam characteristics (eg shape and weight) most likely to meet the prescription requirements designated at the start of the treatment planning process. After numerous beam modifying iterations where size, shape and dose profiles of individual beams are constantly modified by the software, the planning system generates the optimum treatment plan which delivers the closest adherence to the dose limits applied to the target and surrounding normal tissues [9]. To increase the potential for producing a better plan, IMRT generally requires more beams that 3DCRT and often 5-9 beams are used for each fraction [10]

On a conventional linear accelerator, it is the MLC that is key to altering the beam fluence thus making IMRT possible. On a linac, IMRT is typically delivered at fixed gantry angles by either step-and-shoot IMRT or sliding window IMRT. Step-and-shoot IMRT can be achieved by delivering multiple static dose segments within each field (beamlets of dose) which together produce an intensity modulated field. In the sliding window technique, the leaf pairs move constantly across the field at varying rates to deliver the modulated dose for that beam. This approach has been widely used in the treatment of patients with prostate, head and neck, and breast cancers with excellent results [3].

There are many advantages for IMRT over 2D and 3DCRT techniques. As already mentioned, IMRT is capable of sculpting dose distributions to a complex target volume involving concave and convex portions [2]. The technology of IMRT also allows for rapid dose fall-off sparing surrounding critical structures [11].

Improved protection of the surrounding tissues using IMRT has decreased the side effects in comparison to 3DCRT methods in virtually every type of cancer treated [8]. For example, a steep dose gradient in the head and neck region can potentially spare the function of surrounding normal tissues. Many studies have specifically assessed the benefit of IMRT in sparing the parotid glands as xerostomia has been problematic for patients treated with conventional radiation. Salivary flow reduction causes a number of problems for head and neck cancer patients including difficulty chewing, tooth decay, dysphagia, taste loss and altered speech. These manifestations of reduced salivary function can impact quality of life (QoL) for head and neck cancer patients after treatment [11]. Parotid sparing and QoL have been significantly improved in patients who had received IMRT as compared to patients who underwent conventional radiation [12].

The improved dose distribution achieved using IMRT when coupled with IGRT (that allows accurate target localization at the time of treatment delivery) permits dose escalation to the target volume. Numerous studies have demonstrated that dose escalation achieved in IMRT treatments of patients with locally advanced non-small cell lung cancer and prostate cancer, achieved improvement not only in local control, but also clinically meaningful improvement in survival [8].

Another advantage of IMRT is that it allows a simultaneous integrated boost (SIB). SIB allows the delivery of a higher dose per fraction to areas considered at high risk of disease for disease while prescribing a lower dose per fraction to lower risk regions [13].

Despite the many advantages of IMRT, the technique does have some negatives. The greatest concern is that IMRT increases the integral dose received by a patient. It is true that an IMRT plan does result in an overall reduction in the volume of normal tissues receiving a high dose. However, there is a larger volume of normal tissues that is radiated to lower radiation doses [14,15]. This is in-part due to the larger number of beams and beam directions used when treating with IMRT. Also, compared to 2D and 3DCRT, IMRT requires a significantly larger number of MUs to deliver a comparable prescription dose. This results in an increase to the whole body dose as a result of scatter and leakage radiation. Thus IMRT may result in an increased rate of secondary malignancies due to the larger volume of normal tissues being irradiated to lower radiation doses and higher whole body dose [3].

Another criticism of IMRT is that it relies heavily on the target volume being determined by the physician. A sharp dose gradient ensures that minimal radiation is delivered to areas which are not designated at risk by the contours specified. The physician responsible for defining a target volume must have knowledge of clinical and radiographic anatomy and the potential route of spread in order to avoid a marginal miss [11].

Another consideration for IMRT is that it does come with increased financial and logistical cost [11]. These costs include hardware/software upgrades, training cost as well as staffing and QA considerations.

The IMRT treatment techniques described so far (step-and-shoot and sliding window) are fixed gantry techniques. The most recent advances in IMRT are in techniques with a rotating gantry. These rotating gantry techniques include tomotherapy and VMAT.

Tomotherapy:

Tomotherapy, literally meaning “slice therapy” is one of the earliest forms of IMRT [16]. Tomotherapy delivers radiation using a rotating intensity modulated fan beam. Serial, or axial tomotherapy dose distributions are delivered slice by slice, with patients being sequentially translated through the linac gantry rotational plane between slices. Helical tomotherapy distributions are delivered without interruption. Patients are translated smoothly through the bore of the machine as its gantry continuously rotates [17].

Serial tomotherapy was implemented in 1994. In serial tomotherapy, a binary collimator is attached to the head of a conventional 6MV linear accelerator. The collimator comprises of two banks of 20 MLC leaves, which are pneumatically driven to lie either within or outside the fan beam produced by the linear accelerator. The fan beam is modulated by arranging the MLC to lie within the radiation field for varying time intervals. The width of the fan beam can be set to 2 or 4cm projected to the isocentre and the width of each leaf is 1cm at the isocentre. If the target length is greater than the fan beam width, the patient must be irradiated using multiple adjacent arcs [17].

In the mid to late 1990’s, the focus on IMRT development shifted toward the now more widely used fixed gantry techniques (step-and-shoot, and sliding window IMRT). However, in 2002, TomoTherpy Inc., Madison, Wisconsin, USA, developed the Hi-Art machine, specifically designed to deliver helical tomotherapy [16]. The release of the Hi-Art treatment machine renewed interest in tomotherapy.

The helical tomotherapy unit has the appearance of a large CT unit and is essentially the fusion of a CT scanner and a therapeutic linear accelerator [18]. The Hi-Art system is a fully integrated system which includes treatment planning computational capability, a 6MV photon accelerator, a binary collimator mounted on a ring gantry, synchronized patient treatment couch and an MV CT imaging system [3]. As in a CT scanner, the radiation source and the collimator continuously revolve around the patient. Radiation is applied as a fan beam by the rotating gantry and is modulated by a fast pneumatically driven binary collimator. During treatment the patient is moved through the gantry bore resulting in helical dose application [19].

The MLC of the Hi-Art system is equipped with 64 leaves with a 0.625 cm width at the isocentre, thus providing a fan beam length of 40cm. The fan beam width is held constant during treatment, generally at 1, 2.5 or 5cm projected at the isocentre (the smaller the field width, the longer the treatment time). During treatment, the gantry rotates at a constant speed while MLC open 51 times per rotation and close entirely between different projections. Therefore a tomotherapy treatment consists of 51 projections per rotation. As the gantry rotates, the treatment couch translates the patient through the beam by a constant fraction of the fan beam width. This fraction is known as the pitch and typically lies somewhere between 0.2 and 0.5 [17]. Treatment times depend on the prescribed dose per fraction, the length of the target, the depth of the target and the maximum degree of modulation used [17].

Tomotherapy has demonstrated an advantage over fixed gantry IMRT techniques in that it is capable of producing highly conformal dose to a PTV while increasingly sparing dose to organs at risk (OAR) [20]. This potential of tomotherapy is best understood when considering the number of beamlets associated with a tomotherapy plan. In tomotherapy, as the fan beam rotates around the patient it is modulated by the MLC. One leaf of the MLC is considered to have 51 beamlets associated with it during each rotation. As there are a total of 64 leaves, it follows that the treatment may have tens of thousands of beamlets associated with it. Thus tomotherapy is a complex rotational method of treatment delivery that may improve the dose conformity of a treatment plan compared with the fixed gantry method of IMRT that uses a limited number of beam directions [21].

An advantage of tomotherapy is that fields of up to 160cm in length are able to be treated without the need for junctions. The maximum field size on a conventional linac is 40cm x 40cm. Larger fields for IMRT require junctioning and/or extended SSD [17].

An important consideration for tomotherapy is the time needed to complete a treatment. In axial tomotherapy, typically an arc takes 2 minutes to deliver with approximately 1 minute required between arcs to increment the treatment couch a distance of one slice thickness. The treatment time for a seven arc delivery is around 20 minutes. In helical tomotherapy, treatment times are significantly reduced when compared to the serial technique. Helical treatment times are dependent on the prescribed dose per fraction, the length of the target, the depth of the target in the patient and the maximum degree of beam modulation used. A 2Gy per fraction prostate plan typically take around 5 minutes to deliver [17]. For longer treatment times, there is a need for excellent immobilization to limit intra-fractional patient movement [21].

Volumetric Modulated Arc Therapy (VMAT):

Intensity modulated arc therapy (IMAT) was proposed by Yu in 1995. IMAT is a radiation delivery technique where rotational IMRT is delivered on a conventional linear accelerator using conventional MLC [22]. There has been renewed interest in IMAT due to the introduction of linear accelerator delivery control systems that are able to vary the MLC leaf positions, dose rate and gantry rotation speeds during the delivery of arc based IMRT. There has also been a move toward the delivery of rotational IMRT using a single arc [23].

A major advance in IMAT was realized when a novel form of arc therapy called volumetric modulated arc therapy (VMAT) was reported [24]. VMAT is similar to tomotherapy in that a full 360° of beam directions are available. However it is fundamentally different in that the dose can be delivered to the entire PTV in a single arc rotation [25]. In VMAT, treatment is delivered using a cone beam that continuously rotates around the patient. The cone beam is modulated by dynamic MLC, variable dose rate, and variable gantry speed to generate IMRT-quality dose distributions in a single optimized arc around the patient. Clinicians can now deliver continuously modulated dose to the entire tumor volume while sparing normal, healthy tissue [26]

There are several variations of VMAT that are available commercially; RapidArc™ (Varian Medical Systems, Palo Alto, CA, USA), Elekta VMAT™ (Elekta AB, Stockholm, Sweden) and Phillips SmartArc™ (Phillips, Inc, Andover, MA, USA) [10].

Key to the success of VMAT is the optimization algorithm which was introduced in 2008 [24]. Let us consider the optimization process for Varian Medical Systems RapidArc™. Briefly, RapidArc™ consists of optimizing a dose distribution from dose volume objectives. To achieve the desired level of modulation, the optimizer is enabled to continuously vary the dose rate, MLC positions, as well as the gantry speed. The optimization process begins with a small number of control points, gradually increasing them to a sufficient number to ensure dose calculation accuracy [27,28]. The entire gantry rotation is described in the optimization process by a sequence of 177 control points, ie one approximately every 2 degrees [29].

Early results suggest that plans generated with VMAT exhibit a dose distribution equivalent or superior to fixed gantry IMRT [24]. Compared with fixed gantry IMRT, the potential advantage of VMAT include a large reduction in treatment time and concomitant reduction in the number of MUs required to deliver a given fraction size [25]. The significance of this is discussed in more detail in the following section.

Discussion:
Comparing fixed gantry IMRT, Tomotherapy and VMAT.

A number of publications exist that compare fixed gantry IMRT, tomotherapy and VMAT. These publications are usually planning studies that should be interpreted with some caution. In these types of studies, the differences in the quality of the plans produced by the modalities are likely to reflect the areas of expertise of the people performing the dosimetry. Also, there may be intrinsic difference between the planning modalities. Finally, it is possible that the author has a bias toward one technique over another.

In the studies comparing fixed gantry IMRT, tomotherapy and/or VMAT, it is typically reported that each of these IMRT approaches yield treatment plans of improved quality when compared to 3DCRT [20]. It is also commonly observed that there are differences in the plans produced using these IMRT techniques. The differences are typically seen in indicators such as conformity index, homogeneity index, PTV conformation etc. It is important to realize that despite the differences, each technique is capable of producing adequate plans for treatment. In fact, results have demonstrated that the plan quality achieved using fixed gantry IMRT, tomotherapy and VMAT are of comparable quality [23]. The absolute difference observed in dose are small in most cases, thus the clinical significance is unclear. More long term studies are needed to determine if the differences in dose distribution observed are of any real long term significance. Each technique has its own advantages and disadvantages which will be discussed here.

A study by Oliver *et al*., directly compared the planning performance of sliding window IMRT, VMAT and tomotherapy. The study was performed on 4 phantoms designed to represent different anatomical treatment sites including the pelvis and head and neck. Their results suggest tomotherapy is capable of meeting most of their planning objectives and can provide the most uniform dose to the PTV. The trade off for using tomotherapy was that it had the longest planning time, longer estimated treatment time, lower conformity index and higher integral dose. Single and dual arc VMAT plans were delivered in the shortest period of time and were able to provide the most conformal delivery to the PTV. The study demonstrated that 5 and 9 field sliding window IMRT was able to be planned in the shortest time and could be delivered with the lowest integral dose [30].

Like tomotherapy, VMAT plans take longer than fixed gantry IMRT plans to generate. Yoo *et al*., reported that optimization and dose calculation took 2 and 5 minutes for conventional IMRT and approximately 15-20 minutes and 5 minutes for VMAT, respectively. VMAT planning systems are still in the early stages of clinical application. Further improvement of the optimization and dose calculation process will continue to advance the planning process [31].

An important consideration of plan quality is integral dose. As previously discussed, when using fixed gantry IMRT techniques, the volume of tissues receiving a low dose is increased when compared to 3DCRT. Similar observations have also been reported for both tomotherapy and VMAT. Reports are conflicting as to which technique produces the greater integral doses. It is suffice to say that the higher integral doses reported in the three IMRT techniques discussed here could increase the chance of radiation induced secondary malignancies [31].

An advantage that both tomotherapy and VMAT have over the fixed gantry technique is that in the rotating gantry techniques, the uncertainty in selecting the optimal gantry angles for treatment is eliminated. In the fixed gantry technique, the most effective gantry angle may not be obvious. This can result in loss of useful directions prior to the initiation of optimization. In tomotherapy and VMAT, the optimizer can have full access to 360 degrees of rotation [32].

It has been suggested that VMAT holds an advantage over tomotherapy in that VMAT is able to deliver non-coplanar arcs [24,27]. Similarly fixed gantry IMRT techniques are also capable of delivering non-coplanar fields. For some intracranial and head and neck tumours, the use of non-coplanar arcs can provide significant dosimetric benefits due to preferential sparing of adjacent sensitive structures [32]. Supporters of tomotherapy would argue that range of beam angles possible using fixed gantry IMRT or VMAT is limited by the need to avoid collision between the linac head with the patient or couch. Also the time required to deliver non-coplanar IMRT would be increased by the need to repeatedly adjust the couch rotation, a maneuver that also has the potential to disturb the patient setup [17]. Tomotherapy is not capable of delivering non-coplanar fields. However, tomotherapy employs hundreds of thousands of beamlets which can overcome much of this limitation, even in very complex targets adjacent to sensitive structures [32].

When considering fixed gantry techniques and tomotherapy, these two IMRT methods have increased treatment time compared to 3DCRT. This combined with improvements in patient care achieved through IGRT and plan adaption has resulted in an increase in overall treatment times. In order for a radiation therapy department to maintain patient throughput it is necessary to increase the treatment efficiency of IMRT techniques. This is where VMAT has an advantage. Compared with both fixed gantry IMRT and tomotherapy, treatment times are significantly reduced for VMAT [24].

The treatment times using VMAT are reduced because fewer MUs are required to deliver the therapeutic dose distribution via a single arc [24]. Such a reduction in beam-on time can have a strong impact on clinical throughput, ie patients treated per day and waitlist reduction. Also, if a patient spends less time on the treatment couch, the chance of geometrical miss due to intra-fractional movement is reduced [29]. The time saved by reducing beam on time could be used to implement more on-line imaging technologies without increasing the total time in the treatment room [25].

The decrease in MUs achieved using VMAT, partly addresses one of the major concerns of conventional IMRT, the hypothesized risk of secondary malignancies. As previously discussed, a larger number of MUs results in an increase to the whole body dose as a result of scatter and leakage radiation [3]. As VMAT uses less MUs to deliver a dose, the chances of secondary malignancies must also be reduced.

The risk of generating secondary malignancies after radiation therapy is not only dependent on the scatter dose and MUs, but also on the volume of tissue receiving a low dose. As with conventional IMRT and tomotherapy, VMAT also delivers low dose to a larger volume on normal tissue than 3DCRT. Therefore the theoretical risk of secondary malignancies is not eliminated with VMAT [25].

As the implementation of VMAT continues, a realization has developed that optimal dose distributions for complex target volumes can require the use of two or more arcs. When more than one arc is used in VMAT treatments, the benefits of reduced treatment times and a reduction in the possibility of introducing secondary malignancies are reduced [33].

Besides their impact on departmental planning and treatment resources, another important consideration is the availability of the IMRT modalities. Fixed gantry IMRT is routinely used in clinics around the world and is easily the most readily available form of IMRT. VMAT treatments can be performed on any linear accelerator that has had the necessary upgrades to the planning and treatment delivery systems. Such upgrades require financial, training and quality assurance (QA) considerations [33]. The fact that conventional IMRT and VMAT can be performed on general purpose linear accelerators allows for more clinical flexibility [27]. For some patients, the delivery of 3DCRT treatment on a linear accelerator provides a more efficient solution than IMRT techniques. Linacs also provide the ability to deliver electron fields which are a better choice for some treatments such as superficial targets [32]. Tomotherapy requires a dedicated treatment unit and cannot match the versatility of a linac [32]. Consequently, tomotherapy is not as available or widely used as either conventional IMRT or VMAT.

A future direction for both tomotherapy and VMAT is adaptive therapy. Adaptive therapy is a strategy for adapting the progression of the treatments when deviations from that plan are detected. Linear accelerators and the tomotherapy unit are already equipped with imaging technology that allows for CT scans to be recorded for daily treatment. At present, these scans are commonly used within the IGRT process to confirm isocentre positioning prior to daily treatment. In adaptive therapy, the patient’s treatment plan could be computed on the scans obtained routinely at treatment. The accumulated dose from all fractions may be used to track how closely the treatment is following that planned. Interventional steps could be taken at any stage to ensure the final dose delivered to a patient is true to that intended [16].

Conclusion:

The concepts and values behind tomotherapy and VMAT have been introduced here. How these new rotating gantry IMRT techniques relate to conventional fixed gantry IMRT and 3DCRT has also been examined.

Compared to 3DCRT, fixed gantry IMRT is capable of producing dose distributions that conform to the PTV and deliver a significantly reduced dose to surrounding tissues and vital organs. This has come with the cost of increased treatment time and larger volume of normal tissue receiving low radiation doses.

Tomotherapy is a dedicated treatment system that delivers treatment using a rotating intensity modulated fan beam. A therapeutic dose is delivered when a patient is translated smoothly through the bore of the machine as its gantry continuously rotates. Tomotherapy is capable of producing high quality plans that increasingly spare dose to surrounding organs at risk.

In VMAT, treatment is delivered using a cone beam that continuously rotates around the patient. The cone beam is modulated by dynamic MLC, variable dose rate, and variable gantry speed to generate IMRT-quality dose distributions in a single optimized arc around the patient. VMAT has the advantage of significantly reducing the time and monitor units required to deliver a patient’s treatment.

Each of these IMRT techniques produce plans of similar quality. Which technique is most suited to treat a patient will depend on considerations such as the availability of the specific treatment type and its impact on the utilization of departmental planning and treatment resources.

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