ADAPTIVE RADIOTHERAPY WITH SURFACE-GUIDED BREATHING FOR BREAST CANCER PATIENTS IN VIETNAM

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Abstract:
The objectives of the study are an overview of the theoretical basis of Surface Guided Radiation Therapy (SGRT) from previous studies. At the same time, an overview of breast cancer radiotherapy techniques for patients in Vietnam. From there, it is possible to assess which radiation therapy methods are optimal and effective for breast cancer patients in Vietnam. Finally, the study makes recommendations on the use of Surface Guided Radiation Therapy (SGRT) to treat breast cancer for patients in Vietnam.

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1. Introduction

Breast cancer is the most common cancer and the leading cause of death among women in the world and in Vietnam. Currently, breast cancer diagnosis and treatment has made great progress with early detection screening and multimodal treatment combination including: surgery, chemotherapy, radiation therapy, endocrine treatment, targeted treatment. Radiation therapy is a method of using high-energy ionizing radiation to kill cancer cells, which is commonly indicated in the treatment of breast cancer. According to studies around the world, adjuvant radiation therapy after breast cancer surgery reduces the rate of recurrence and metastasis while extending the overall survival time for breast cancer patients.

In recent years, the clinical use of Surface Guided Radiation Therapy (SGRT) by scanning optical surfaces to locate patients, track movement in the section, and respiratory gate techniques has increased. Generally, SGRT systems use a combination of projectors and one or more camera units to register a patient's real-time 3D surface. The reference surface associated with the treatment center position is used to calculate the correction required for the patient position in translational and rotational directions. There are four main optical surface scanning technologies used in radiotherapy, laser scanners, time-of-flight systems, floating vision systems, and structured lighting systems. Optical surface scanners, with their high spatial and temporal resolution, have proven to be an important addition to the radiotherapy procedure involving patient positioning and monitoring. SGRT can be considered a "four-eyed principle" tool that allows continuous monitoring of the patient's location, thus improving patient safety and comfort, while standardizing workflow (greater accuracy and reproducibility). In addition, it is capable of improving clinical outcomes through precise target irradiation, while removing normal tissues. In terms of patient positioning, SGRT is an effective tool for reducing overall treatment time and minimizing image dosage, since: i) it provides information online in the room about the patient's entire surface and location, ii) for surface tumors (where surface deviations can serve as an alternative to tumor movement) SGRT allows for more precise positioning than 3-point lasers and may allow for a reduction in the number of daily images in some cases; iii) for deeper tumors (there is no direct correlation between surface deviation and tumor movement), daily imaging is still required, but SGRT may reduce the time required to register images and prevent the need for multiple images. Although the imaging dose can be considered negligible compared to the whole-body dispersion dose from photon processing, SGRT can be defined as an image-guided step that can be performed without ionizing radiation as suggested in AAPM TG 75 to reduce the imaging dose. Since SGRT systems provide real-time movement tracking of the patient's surface throughout the entire treatment section, an additional level of safety is added to the radiotherapy procedure. The beam can be held if parts of the patient's surface deviate from the reference position based on a planned CT setup or if the calculated eccentricity exceeds a certain threshold. One of the most promising applications of SGRT is the delivery of controlled radiotherapy to tumor sites near the surface of the skin (e.g., breast cancer) using Deep Breath Keeping Inspiration (DIBH) and Voluntary DIBH (vDIBH). Another application developed in recent years is the use of SGRT in whole brain radiotherapy (WBRT) or stereotactic radiosurgery (SRS). Here, an SGRT system is capable of monitoring the patient's surface in an open face fixation mask in flat and non-uniform treatments. SGRT has also been applied in special techniques such as accelerated partial breast irradiation (APBI), stereotactic body radiotherapy (SBRT), and limited use in pediatrics. The current review aims to provide a summary of recent clinical advances in SGRT and the latest research findings applied to modern SGRT-based treatments, with prospects for future application areas.

2. Literature review

2.1. Radiation therapy and cancer

Radiation therapy can cure cancers, prevent them from returning, or inhibit tumor growth. Radiation therapy is also indicated in some cases to alleviate symptoms caused by cancer such as bleeding, pressure, pain.

Technically, radiation therapy can be divided into:

External beam radiotherapy: the source of radiation is located on the outside of the patient, emitting the beam to the tumor.

Close-pressure radiation therapy (also known as internal radiation therapy): the source of radiation is delivered close to the tumor, can be applied to the surface of the tumor (e.g. radiation therapy for skin cancer, cervical cancer) or through the tissue into the core of the tumor (e.g. radiation therapy of some oral cancers,prostate cancer)

Radiopharmaceuticals: radioactive isotopes introduced into the patient's body (orally or by infusion) deliver radiation to cancer cells (e.g. thyroid cancer treatment with Iodine 131 or pain treatment with samarium)

At high doses, radiation therapy kills or inhibits the growth of cancer cells by damaging their DNA. When DNA is damaged, cancer cells stop dividing or are broken down and removed from the body.

Radiation therapy cannot kill cancer cells immediately. As a result, it takes days or weeks of treatment for enough time to damage DNA and kill cancer cells. After the end of radiation therapy, the cancer cells continue to die within weeks or months.

Radiation treatments

There are two main types of radiation therapy: external beam radiation therapy and internal radiation therapy. The choice of radiation therapy should be based on many factors, including:

Type of cancer

The size of the tumor

Tumor location in the body

The distance of the tumor from neighboring healthy organs.

The patient's medical condition and medical history

Other cancer treatments in use

The age of the person and some other factors

2.2. Surface radiation therapy

Surface Guided Radiation Therapy (SGRT) is one of the most advanced techniques available today for accurate treatment, improving the quality of treatment and reducing side effects for patients. The outstanding advantages of this technique include:

• Position the patient based on the surface of the skin, ensuring more accuracy in setting the patient's position and posture before treatment, no pain for the patient because there is no need for tattoo marks on the skin during simulated CT scan.

• Real-time patient mobility monitoring during treatment beam delivery, integrated with the radiotherapy machine's auto beam hold function, ensuring accuracy < 1mm when treating intracranial lesions and < 3mm when treating extracranial lesions.

• Allows the Deep Inhale Breath Hold (DIBH) technique to be performed to help reduce cardiac side effects in left breast cancer patients.

Using infrared surveillance cameras, patients do not receive additional doses of radiation as in conventional image-guided radiotherapy techniques.

3. Methods

In cancer radiotherapy, creating an optimal radiation therapy plan with the achievement of a highly focused radiation therapy dose on the lesion area, the minimum dose of radiation therapy on the surrounding healthy institutions plays an important role in improving the effectiveness of treatment and minimizing complications. 3D-CRT radiation therapy helps to create a relatively good radiation therapy plan, but it is still limited in many cases, especially for cancers in sensitive locations, near important organs such as rectal cancer. Dose-modulated (intensity) radiotherapy according to tumor morphology - IMRT is a modern technique in clinical practice, it is born to help create a more perfect radiation therapy plan with reverse planning.

In Vietnam, the radiation therapy industry is considered to be in the development stage. The use of radiation therapy devices for cancer patients has been underway for a long time, but the technique is classic and simple. Nowadays, with the rapid development of science and technology, many modern radiotherapy equipment and techniques have also been present in Vietnam, especially with IMRT radiation therapy technique. IMRT radiotherapy was first deployed at K Central Hospital in 2008 for patients with throat cancer. Currently, this technique is being deployed for a number of other common cancers including rectal cancer. In order to meet that development, it is necessary to have documents mentioning the basic knowledge of IMRT radiation therapy procedures for rectal cancer patients to contribute to serving oncologists, nuclear medicine, engineers, radiotherapy technicians,student... Furthermore, it is intended to confirm the feasibility of IMRT by means of jaws-only and reasonable distribution of doses at beer volumes (TV) as well as doses at adjacent healthy institutions (OAR).

4. Results

Surface Guided Radiation Therapy (SGRT) is a form of radiotherapy that uses surface recognition systems and tracks the actual time of change of the surface based on infrared light or in the visible light range, which has been on the market since about 2017 [H.5]. Optical Surface Monitoring System (OSMS) is not usually used alone but in combination with X-ray positioning systems for added accuracy. The outstanding advantage of this system is that the absence of X-rays can be continuously monitored during radiation therapy on a large scale, for soft tumors (breast tumors, soft tissue sarcoma), or used to treat breathing mobile tumors (liver tumors,lung tumors, breast tumors).

Modern radiation therapy aims to treat the dead while minimizing the dose of radiation to nearby normal tissue, to minimize the acute and late effects of the treatment. The leading technological approaches are intensity modulated radiotherapy (IMRT) and intensity modulated proton therapy (IMPT) in combination with image-guided radiotherapy (IGRT). IMRT and IMPT are characterized by a more consistent dose distribution, which is often accompanied by a high dose gradient. In turn, movement management and accurate patient positioning become more important. Several imaging guidance systems are available for radiation therapy (RT), with 3-D volumetric imaging (3D) with conical beam computed tomography (CBCT) as the gold standard. In recent years, surface imaging (SI) using an optical surface scanning system has been included in the IGRT toolbox. The SI CatalystTM system (C-rad Positioning AB, Uppsala Sweden) visualizes the 3D surface image of the patient's terrain and directly correlates the patient positioning with the originally planned location. SI provides the largest field of view in RT, does not cause radiation exposure, provides real-time feedback and submillimeter spatial resolution. These characteristics are suitable for both patient positioning and motion management in RT. Integration with linac provides automatic beam control and seat displacement, which requires strict attention to the quality assurance (QA) of SI systems. To integrate beam control, beam delay time (beam on and off beam) must be described, which requires PIN diode circuitry to evolve as a QA tool. What is more important are the ray off delay measurements, as it represents the time it takes to continue irradiating after the beam-holding signal is sent from the SI system. Automatic seat displacement is calculated using a deformable image registration (DIR) algorithm, unique to the CatalystTM surface scanning system. The accuracy of positioning depends on the image registration process and so a deformable chest illusion has been developed to test the accuracy of DIR with anatomically realistic deformations present as a QA tool. Compared to traditional 3-point positioning for patient positioning, this thesis has shown that SI improves positioning for both breast and prostate cancer patients. In addition, SI workflows have proven to be time-efficient for locating prostate cancer patients. One respiratory movement management technique is deep inhalation (DIBH), where the patient is instructed to hold his breath during treatment. The intended use of DIBH is to create an anatomical gap between the therapeutic volume and surrounding at-risk organs (OAR). Comparative treatment planning studies, within the scope of this dissertation's work, suggest that DIBH may be an effective method for both left breast cancer and Hodgkin's lymphoma (HL) to reserve doses for the heart. For HL, a combination of IMPT and DIBH was found to be a prophylactic dose for OAR, however, due to the spread in target localization, individual deviations from this treatment technique were observed. Real-time feedback from the surface imaging system was used to investigate the regenerative capabilities of DIBH to ensure accurate dose delivery during treatment delivery. High reproducibility of the focal position in DIBH has been observed, however, in a few breaths, greater deviations have occurred, which drives the need to use beam-controlled tolerances for the focal point. The overall conclusion is that optical imaging systems, developed in the study of this thesis, can be used as an imaging tool to more accurately and quickly establish patients, monitor internal movements, and reduce doses for OAR during treatment in DIBH.

5. Conclusion

In a workflow known as surfaces guided radiotherapy (SGRT), the reference surface for the patient setup can be generated in one of two different ways: either it can be the body surface that was produced or generated from the automatic contouring in the treatment planning system (TPS) (i.e., DICOM), or it can be a SI that was generated from a SentinelTM or CatalystTM system at CT. Both of these methods are described further below. The clinical workflow for the patient determines the specific reference surface that is utilized for the patient. The information derived from the treatment plan is loaded into the CatalystTM work station, where it is followed by the assignment of a template to the individual being treated. Target-specific templates (such as those for the thorax, pelvis, head and neck, etc.) and patient-specific templates with customized parameters are both possible. A tolerance table for the treatment isocenter, surface matching, and the surface color map are all included in the template. The default values for the scanning volume, calculating resolution, and smoothing of the breathing motion are all stored in the template. After the OSS system has determined the position of the patient, the "Auto-Go-To" function can be utilized to move the couch into the appropriate position in an entirely hands-free manner. Because the CatalystTM is connected to the linac for the purpose of beam control, the beam will be interrupted if the system detects larger deviations than the ones set in the template.

The template specifies the acceptable range of motion for patient placement tolerances. In a perfect world, the tolerance would be zero, but because patients move during and after the positioning operation, a tiny setup tolerance (usually 2mm) is provided. This is because the tolerance should be small; in fact, it should be zero. Tolerances for the setup need to be met before the operator can move on to treatment delivery. If these are not met, the operator cannot proceed.

The template is where the determination of the scanning volume that is used for patient positioning and monitoring takes place. The surface that is included in the scanning volume needs to have anatomical topography, reflect light, and ideally include the isocenter in order for an accurate computation of the position of the isocenter to be possible. The magnitude of the scanning volume has a role in determining the percentage of the scanning volume that will be used into the isocenter computation. Calculations can be completed more quickly on a smaller surface; however, significant anatomical features may be missed if the surface is too small. For this reason, a larger surface is typically employed, even though it takes longer to complete the calculations.

The patient's respiratory motion is significant mostly in the thorax and belly, and this can have an effect on where the isocenter position is estimated. The live surface has a mean value filter applied to it in order to reduce the impact of the breathing motion. In clinical settings, the typical range is between 4 and 8 seconds.

Patient posture modifications are performed manually with the guidance of a color map that is projected onto the skin of the patient. In the beginning stages of the CatalystTM DIR, local deformations are determined by using an iteration based on the closest neighbor in conjunction with a non-linear approach between the SI pair. If the distance between the live image and the reference image is greater than a user-defined threshold value in the template, then the user will be able to see any local deformations that have occurred on the patient's skin. The color map is projected onto the patient's skin by the system, which provides real-time updates of the patient's position. The therapist employs their own two hands to effect any necessary corrections.

The CatalystTM was initially developed as a single camera system, and a master camera was initially positioned in the ceiling above the treatment couch. However, because of the shadow that the camera casts, crucial surface area that is located above the isocenter might be missed in some clinical instances if only one camera is used. The CatalystTM HD system is a three-camera solution, with the master camera located in the same place as the single camera system, along with two side cameras installed in a 120-degree angle from each other. The CatalystTM HD system also includes a microphone. Increased information regarding the patient's posture can be obtained as a result of this setup, which permits a full 360-degree view of the object being scanned.

The movements of the patient is monitored by the OSS system while the treatment is being delivered. Before treatment begins, the motion of the patient surface and the computed shift in the isocenter are both recorded. Tolerances for the observed motion are then defined in the target-specific or patient-specific template. Before the treatment is actually administered, a daily reference surface is obtained. A floating mean value of the patient position is added after the reference image has been obtained over a period of many seconds. This is done in order to reduce the impacts of the breathing motion. The daily reference surface is matched with the live surface, as well as allowances for changes in the patient posture and shifts in the calculated isocenter. These shifts in the computed isocenter regulate whether or not the therapy beam should be turned on or off. The OSS system is responsible for calculating any shifts in the isocenter that are brought on by patient motion. The acceptable intrafractional motion should be established by the margins in the treatment plan. The tolerance for the isocenter shift should relate to this acceptable motion. One of the limiting reasons for patient monitoring is the fact that the same size of the scanning volume is utilized for both patient positioning and motion tracking. Commonly, the surface tolerance is chosen to include the FB respiratory motion in order to avoid frequent beam interruptions. Because the same surface tolerance is applied to the entirety of the surface contained inside the scanning volume, the user is unable to designate certain regions of the object as being more significant than others. This is one of the factors that is considered to be a limitation.

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