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ORIGINAL ARTICLE

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Evaluation of Hounsfield Numbers and Electron Density for a CT Simulator and Their Importance for Radiotherapy Treatments

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Abstract

Since its introduction in the early 1970s, computed tomography (CT) has significantly improved accuracy in radiotherapy planning by enhancing geometric volume definitions and dose calculation distributions. CT scans provide a distribution of attenuation values relative to water, measured in Hounsfield units (HUs), which correlate with the linear attenuation coefficient (μ). These coefficients depend on the electron density and elemental composition of the tissues.

Using fundamental physical information, such as the size, shape, and location of inhomogeneities in anatomical structures combined with HU values from the CT scan, the data is integrated into the treatment-planning system's database. This integration enables precise planning for radiotherapy treatments. To establish the HU scale for our CT simulator, our medical physics department scanned the CIRS phantom. By analyzing the phantom images, we determined the HU calibration curve for our CT-Sim system. Using this calibration, along with data from our medical linear accelerator, we created specific photon treatment beams for radiotherapy applications.**(International Journal of Biomedicine. 2025;15(2):358-363.)**

Keywords: Hounsfield number • CIRS phantom • CT – Sim • photon beam

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Abbreviations

CT, computed tomography; **ED**, electronic density; **HU**, Hounsfield unit; **TPS**, treatment planning system.

Introduction

In a radiotherapy treatment planning system (TPS), the relationship between Hounsfield unit (HU) values and electron density is established by scanning an electron density phantom, creating a calibration curve that links HU values to known electron densities. This curve is then applied to the patient's CT scan, allowing the TPS to convert HU values from the patient's anatomy into electron densities, which is critical for accurate dose calculation. CT number is a special number that is a normalized value of the calculated X-ray absorption coefficient of a pixel (picture element) in a computed tomogram. The absorption coefficient of a tissue varies with the nature of the tissue and the energy (kV) of the X-ray beam. However, if the tissue absorption coefficient is related to that of the water absorption coefficient at the same kV, a reference number independent of kV change can be obtained. This number is called a CT number. CT number is represented by a specific unit or number called the Hounsfield

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unit. By ensuring consistency in scan parameters (e.g., 120 kV) and maintaining regular QA with phantoms, the TPS can precisely account for tissue inhomogeneities, delivering the planned dose effectively to the target.

In medical imaging, particularly in CT (computed tomography) scans, a voltage of 120 kV is common. A voltage of 120 kV provides a good balance between image quality and radiation dose. It generates X-rays with sufficient energy to penetrate most tissues, producing clear and detailed images essential for accurate diagnosis. At 120 kV, the X-ray spectrum is well-suited for differentiating between various types of tissues. This energy level enhances contrast resolution, distinguishing between structures with similar densities, such as soft tissues and blood vessels, more easily. While higher voltages (e.g., 140 kV) can produce even more penetrating X-rays, they also increase the radiation dose to the patient. Conversely, lower voltages (e.g., 80-100 kV) reduce the dose but may not penetrate as effectively, especially in larger patients. The 120 kV setting offers a compromise, optimizing image quality and patient safety. Many CT protocols and diagnostic criteria are standardized based on 120 kV scans. This consistency ensures that images can be compared across different machines and institutions, facilitating accurate diagnoses and follow-up. CT scanners are often calibrated and optimized for performance at 120 kV. This standardization ensures reliable and consistent image quality across different scans and patients. These factors together make 120 kV a widely adopted setting in CT imaging, balancing the needs of image clarity, diagnostic accuracy, and patient safety.

On the other hand, the selection of 120 kV in CT scanning is also related to the electronic density (ED) of tissues. Electronic density, on the other hand, refers to the number of electrons per unit volume of a material. In medical imaging, ED is an important factor in determining the attenuation of X-rays by tissues. ED is directly related to the atomic number and density of the material, and it plays a critical role in the absorption and scattering of X-rays. The electronic density of a tissue affects its X-ray attenuation properties. At 120 kV, the X-ray photons have an energy level that optimizes the differentiation between tissues with different electronic densities. This is crucial for producing high-contrast images where different tissues and structures can be clearly distinguished. [1-4]

X-ray interactions with tissues involve both Compton scattering and the photoelectric effect. The probability of these interactions varies with the energy of the X-rays and the electronic density of the tissues. At 120 kV, there is an optimal balance between these two effects, enhancing the contrast between tissues with varying electronic densities, such as bone, muscle, fat, and organs. CT scanners are often calibrated at 120 kV to represent the electronic densities of different tissues accurately. This ensures that the Hounsfield units (HU) assigned to different tissues are consistent and reliable, aiding in diagnosing and assessing various conditions. In some advanced imaging techniques, such as dual-energy CT, different kV settings are used to distinguish materials based on their electronic density differences. While dual-energy CT uses two different kV settings, the 120 kV setting is a reference point for understanding how electronic density affects X-ray attenuation at a standard energy level. Using 120 kV, CT imaging achieves a balance that makes it possible to effectively visualize and differentiate tissues based on their electronic density, contributing to accurate diagnostic imaging.

Methodology

Hounsfield units (HU) and ED are important concepts in CT imaging, but they refer to different aspects of tissue characterization. Hounsfield units are a quantitative scale for describing radiodensity in CT imaging. They represent the degree to which different tissues attenuate X-ray beams. The HU scale is standardized, with water defined as 0 HU and air defined as -1000 HU. Other tissues fall within this range: bone might be around +1000 HU, and fat might be around -100 HU.

HU values are derived from the CT scanner's measurements of X-ray attenuation, which depends on the tissues' density and atomic number. HU values are used clinically to differentiate between types of tissues and to identify abnormalities. For example, they help distinguish between cysts, tumors, and normal tissue based on their radiodensity.

However, electronic density refers to the number of electrons per unit volume in a substance. It influences how a material interacts with X-rays. Unlike HU, electronic density is not expressed on a standardized scale. It is a physical property measured in units like electrons per cubic centimeter. Electronic density directly affects the attenuation of X-rays due to interactions like Compton scattering and the photoelectric effect. In CT imaging, the electronic density of tissues contributes to the overall attenuation that is measured and translated into HU. Higher electronic density generally means higher X-ray attenuation, resulting in higher HU values.[1,3,5,6]

HU values are an indirect measure based on X-ray attenuation, which is influenced by electronic density and the atomic number and physical density of the tissue. Electronic density is a more direct measure of the number of electrons in a given tissue volume.

HU is directly used in clinical practice to interpret CT images. Electronic density is a fundamental physical property affecting attenuation but is not directly displayed on CT images.

HU values are calculated using the formula:

$$HU = 1000 \, x \, \frac{\mu_{tissue} - \mu_{water}}{\mu_{water}}$$

where μ_{tissue} is the linear attenuation coefficient of the tissue, and μ_{water} is the linear attenuation coefficient of water. This formula shows how attenuation is normalized to water to create the HU scale.

While electronic density is a fundamental physical property influencing X-ray attenuation, HU is the practical metric used in CT imaging to represent and interpret that attenuation in a clinical context.

In radiotherapy treatment planning systems, there is a key relationship between HU values from CT scans and the electronic density of tissues. This relationship is critical because it allows the conversion of HU values into electron densities, which are used for accurate dose calculations in radiation therapy.

Results

In radiotherapy, a calibration curve is created to convert HU from CT images to relative electron densities (RED) compared to water. This curve is essential because dose calculations in treatment planning depend on knowing the electron density of tissues, which affects how radiation is absorbed and scattered. Figure 1 shows our calibration curve for Siemens Sensation CT for 120 kV.

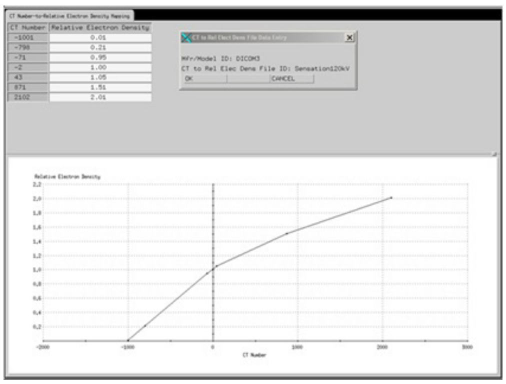

Fig. 1. *Relative Electron Density vs CT Number curve for 120 kV.*

The calibration curve is specific to each CT scanner and the energy (kV) used for scanning. Different tissues (bone, muscle, fat, air, and water) have distinct HU values corresponding to specific electron densities. The relationship is generally linear for soft tissues but becomes more complex for high-density materials like bone; our data are represented in Table 1 after we have scanned the CIRS phantom with different kV.[4,7-9]

In radiotherapy, the dose deposited by the radiation (photons or particles) depends on the electron density of the tissues. Tissues with higher electron densities (e.g., bone) attenuate the radiation more, leading to greater dose absorption, whereas lower-density tissues (e.g., air or fat) allow radiation to pass through with less interaction.

Accurate dose calculation requires knowing the electron density, which determines the therapeutic radiation's path and energy deposition. The HU-to-electron density conversion allows the TPS to model how the radiation beam interacts with different tissues, ensuring that the prescribed dose is delivered accurately to the target (tumor) while sparing surrounding healthy tissues.

In photon-based radiotherapy, the HU-to-electron density conversion is used to calculate how the photon beams interact with tissues. This affects the attenuation, scatter, and energy deposition in the patient.

Modern TPS systems use sophisticated algorithms to correct any non-linearities in the HU-electron density relationship, particularly at high HU values (e.g., for bone or metallic implants). These corrections ensure that the dose

Table 1.
The data of ED and HU obtained for different CT kilovoltage parameters.

		80 kV		100 kV		120 kV	
Nr.	CIRS Material	ED	HU	ED	HU	ED	HU
1	Lung	0.634	-790.266	0.634	-812.62	0.634	-809.01
2	Lung	0.634	-806.588	0.634	-802.22	0.634	-799.47
3	Lung	1.632	-471.15	1.632	-494.87	1.632	-493.86
4	Lung	1.632	-495.799	1.632	-483.74	1.632	-483.73
5	Soft tissue	3.171	-78.863	3.34	-269.24	3.34	-252.53
6	Soft tissue	3.17	-89.231	3.171	-73.72	3.171	-67.83
7	Thoracic	3.261	-35.32	3.171	-66.918	3.171	-63.768
8	Thoracic	3.261	-44.547	3.261	-31.25	3.261	-37.722
9	Moveable cylinder	3.34	-311.459	3.261	-28.392	3.261	-24.193
10	Bone	3.37	316.765	3.483	38.904	3.483	37.859
11	Muscle	3.483	28.765	3.483	42.57	3.483	38.992
12	Muscle	3.483	36.997	3.516	48.858	3.51	44.664
13	Liver	3.516	39.034	3.51	52.576	3.516	45.305
14	Liver	3.51	47.475	3.73	251.679	3.73	216.532
15	Bone	3.73	304.502	3.73	260.657	3.73	226.184
16	Bone	4.862	1214.1	4.862	1002.32	4.862	859.802
17	Bone	4.862	1211.905	4.862	1003.5	4.862	862.202

distribution is calculated as accurately as possible, even in complex anatomical regions.

The relationship between HU and ED in radiotherapy treatment planning is fundamental for accurate dose calculation. By converting HU values from CT images into electron densities, the TPS can model how radiation will interact with different tissues, enabling precise and effective treatment planning. The calibration of this relationship is critical to ensure that the correct dose is delivered to the target area while minimizing damage to surrounding healthy tissues.

The relationship between the data measured from the linear accelerator (linac) at a reference depth of 10 cm in water and the Hounsfield unit (HU) to the electron density (ED) curve from the CT scanner is fundamental for ensuring accurate dose calculation in radiotherapy.[10,11]

When measuring data from the linac, the dose distribution is often recorded as a function of depth in a water phantom. The reference point is typically 10 cm deep in water, which represents the attenuation and energy loss of the radiation beam as it travels through a uniform medium (water).

Water is used as the standard material because its electron density is similar to soft tissues. The PDD curve represents how much dose remains at different depths, with 100% of the dose typically being normalized to a depth of maximum dose (e.g., at 1.5 to 2 cm for photon beams). This curve allows us to understand how the beam behaves in a homogenous medium; Figure 2 shows the measurement of PDD in water for energy 6 MV and field size 10 × 10 cm^2, measured with a PTW Thimble chamber.

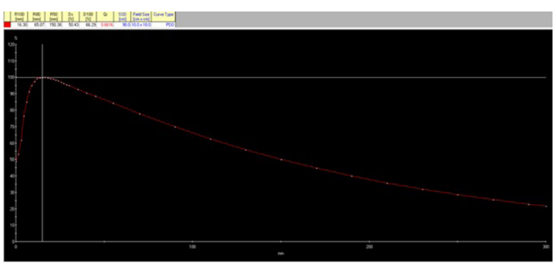

Fig. 2. PDD curve for energy 6 MV and field size 10 x 10 cm^2.

The HU to electron density curve derived from CT imaging allows the treatment planning system to account for variations in tissue composition (bone, muscle, fat, air) when calculating dose distributions. Different tissues have different X-ray attenuation properties (HU values), which are converted into relative electron densities (RED) compared to water, which is critical for dose calculation.

Human anatomy is not a uniform medium like water. Tissues with different electron densities will attenuate the radiation beam differently. The HU-ED curve provides a way to adjust the dose calculations based on these variations, ensuring that the dose is accurately calculated for soft tissues, bones, and other materials (e.g., lung or air pockets).

The linac's depth dose data, measured in a homogenous water phantom, serves as the baseline for how radiation interacts with a uniform medium. However, the patient's anatomy is heterogeneous, with various tissues that have different densities and attenuation characteristics. The HU-ED curve is used to modify the baseline dose data (such as PDD) from the linac to account for the effects of these different tissues.[3,4,6,9,10,12]

When planning treatment, the TPS uses the HU-ED conversion to adjust the dose deposition based on tissue-specific properties. For example, if the CT shows bone (which has a higher electron density than water), the TPS adjusts the dose to account for the increased attenuation, as the beam will lose more energy passing through denser tissue. Conversely, in lung tissue (with lower electron density than water), the beam attenuates less, and the TPS adjusts accordingly.

The TPS combines the linac's measured dose data (for water) with the patient-specific HU-ED curve. Essentially, the PDD curve from water is "scaled" by the electron density differences in the patient's anatomy to reflect how the radiation beam interacts with non-water tissues.

Modern TPS uses algorithms (like convolution/ superposition or Monte Carlo methods) to calculate dose distribution based on the combination of measured linac data and the patient-specific HU-ED curve. The HU-ED curve ensures that the TPS considers how different tissues modify the beam as it travels through the patient's body, adjusting the depth dose curve accordingly.[10]

The electron density (derived from HU) also helps calculate the "effective path length" that the radiation beam travels through the tissue. If the tissue density is higher than water, the effective path length is longer, meaning the beam attenuates more than it would in water. The TPS uses the HU-ED data to correct this inhomogeneity.

To ensure accuracy, treatment plans are often tested in phantoms (Figure 3) (sometimes anthropomorphic phantoms with tissue-equivalent materials), where the calculated dose distributions are compared to the actual measured doses. This step helps validate that the TPS correctly uses the linac data and the HU-ED curve to calculate dose in heterogeneous mediums.

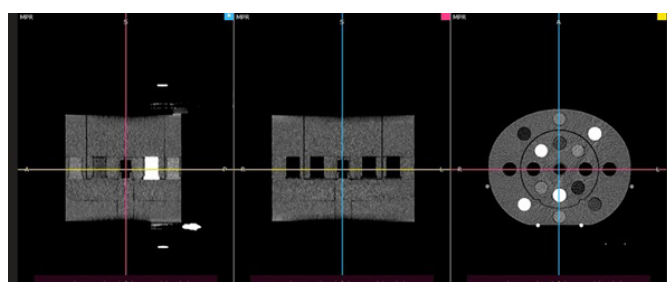

Fig. 3. Three-dimensional (3D) view of CIRS phantom scanned with 80 kV.

The data from the linac, measured at a reference depth of 10 cm in water, provides a baseline for how radiation behaves in a homogeneous medium. However, in clinical practice, the patient's anatomy is heterogeneous, with different tissue densities affecting how the radiation beam deposits dose. The HU-ED curve, derived from CT scans, provides a means of adjusting the linac's water-based depth dose data to account for these tissue differences. Together, these data allow the TPS to calculate accurately and model dose distribution in the patient, ensuring that the prescribed radiation dose is delivered effectively to the tumor while sparing healthy tissues.

The treatment planning system uses an algorithm to compare the electron density (ED) and Hounsfield units (HU) from a patient's CT scan to the known HU-ED relationship obtained from scanning a phantom, Figure 4.

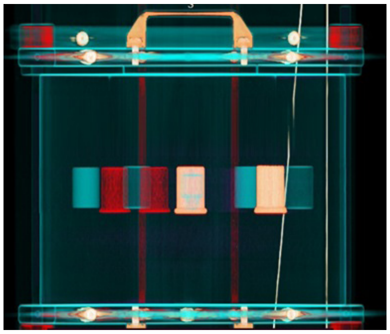

Fig. 4. *CIRS phantom 3D mode scanning by 120 kV.*

The CT scanner is used to scan a tissue-equivalent electron density phantom that contains inserts made from different materials, each representing tissues of varying densities (e.g., bone, muscle, lung, fat, water). These materials have known electron densities relative to water.

The phantom's inserts are imaged at 120 kV (the same kV setting used for patient CT scans), and the resulting Hounsfield units for each material are recorded. Since the electron densities of these materials are known, a calibration curve is created by plotting HU against electron density.

- For example, water will have a HU of 0 and an electron density of 1.0 (relative to water).
- Bones may have a HU of +1000 and an electron density of 1.8.
- Air will have a HU of -1000 and an electron density close to 0.

This curve establishes the relationship between HU and ED for the specific CT scanner and scan parameters (like 120 kV), creating a reference point that will later be used in patient dose calculations.

The patient is scanned with the same CT scanner at 120 kV to generate a 3D image of their anatomy. Each voxel in the CT image is assigned to a Hounsfield unit (HU) based on the tissue's X-ray attenuation characteristics.[3,5,7,13,14]

This scan provides a detailed map of HU values throughout the patient's body, representing different tissues such as soft tissue, bone, fat, and air-filled cavities.

The TPS uses the HU values from the patient's CT scan and compares them to the calibration curve obtained from the ED phantom. For each HU value in the patient's scan, the TPS finds the corresponding electron density using the HU-ED curve from the phantom scan.

- For example, if a voxel in the patient scan has a HU of +300 (indicating muscle tissue), the TPS looks at the calibration curve and finds the electron density for HU = +300. Let's say the curve indicates an electron density of 1.05 for this HU value. The TPS assigns this electron density to that voxel.
- For bone tissue with a HU of +1000, the TPS might find an electron density of 1.8 from the curve and assign that value to the corresponding voxel in the patient scan.

After the TPS has converted all the HU values from the patient's CT scan into electron densities using the HU-ED calibration curve, an electron density map of the patient is created. This map represents the variation in electron density across different tissues.[12]

The TPS then uses this electron density map to calculate how radiation will interact with and be absorbed by different tissues. Higher electron-density tissues (like bone) will attenuate the beam more than lower electron-density tissues (like lung or fat), and the TPS adjusts the dose distribution accordingly.

It is crucial that the CT scanner's energy (120 kV) used for both the phantom and the patient is the same because the HU values depend on the X-ray energy. Changes in kV can shift the HU-ED relationship, so consistent scan parameters ensure the accuracy of the calibration curve.

To maintain accuracy over time, periodic quality assurance (QA) is performed using the same or similar ED phantoms. This ensures that the HU-ED curve remains accurate for the CT scanner used and that TPS calculations based on patient scans are reliable.

Most TPS systems directly apply the HU-ED curve to convert the patient's HU values into relative electron densities. This method is typically straightforward and ensures accurate dose calculation in heterogeneous tissues.

Some more advanced TPS algorithms, such as Monte Carlo methods, may refine the conversion process by considering not only the HU-ED relationship but also additional factors like beam energy spectra, tissue composition, and scatter effects. These models simulate the actual interactions of the radiation beam with different tissues in much greater detail. Figure 5 shows the simulation of isodoses for energy 6MV by the Superposition/Convolution algorithm of TPS.

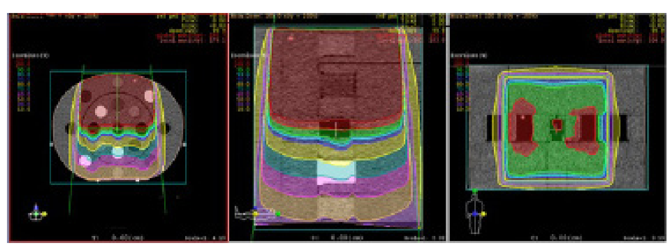

Fig. 5. *Simulation and creation of isodoses based on HU number and ED for energy 6 MV.*

For high-density materials (e.g., metal implants or dense bone), nonlinear corrections may be applied to ensure the electron density conversion remains accurate, especially since the HU-ED relationship can become nonlinear at higher HU values.

In radiotherapy TPS, the relationship between HU and electron density is established by scanning an electron density phantom, creating a calibration curve that links HU values to known electron densities. Then this curve is applied to the patient's CT scan, allowing the TPS to convert HU values from the patient's anatomy into electron densities, which are critical for accurate dose calculation. By ensuring consistency in scan parameters (e.g., 120 kV) and maintaining regular QA with phantoms, the TPS can precisely account for tissue.[1,2,14]

Conclusion

The relationship between HU and ED in radiotherapy treatment planning is fundamental for accurate dose calculation. By converting HU values from CT images into electron densities, the TPS can model how radiation will interact with different tissues, enabling precise and effective treatment planning. The calibration of this relationship is critical to ensure that the correct dose is delivered to the target area while minimizing damage to surrounding healthy tissues.

Using 120 kV is a considered choice that helps ensure the effective dose is kept as low as reasonably achievable (ALARA) while still providing the necessary image quality for accurate diagnosis. By using 120 kV, CT imaging achieves a balance that makes it possible to effectively visualize and differentiate tissues based on their electronic density, contributing to accurate diagnostic imaging.

Electronic density is a fundamental physical property influencing X-ray attenuation, and HU is the practical metric used in CT imaging to represent and interpret that attenuation in a clinical context.

The relationship between HU and electron density in radiotherapy treatment planning is fundamental for accurate dose calculation. By converting HU values from CT images into electron densities, the TPS can model how radiation will interact with different tissues, enabling precise and effective treatment planning.

The results obtained show the dependence between the CT number (HU) and electron density (DE) of a certain tissue. At the voltage value of 80 kV, it is seen that the maximum values of the HU number are those that belong to the bone part, while the minimum values are those that belong to the lung part at the moment when the organ functions in exhaling air.

When we apply voltage values of 100 and 120 kV, it is seen that the values of the HU number decrease for the bone, but the values for the lung change very little compared to the values of the bone. We can precisely determine the type of tissue to which the image belongs simply by knowing the interval of values of certain tissues. Also, based on the contrast of the gray color, we evaluate the results of which part of the body the image obtained belongs.

Competing Interests

The authors declare that they have no competing interests.

References

1. Knöös T, Wieslander E, Cozzi L, Brink C, Fogliata A, Albers D, Nyström H, Lassen S. Comparison of dose calculation algorithms for treatment planning in external photon beam therapy for clinical situations. Phys Med Biol. 2006 Nov 21;51(22):5785-807. doi: 10.1088/0031-9155/51/22/005. Epub 2006 Oct 24. PMID: 17068365.
2. Palmans H, Nafaa L, De JJ, Gillis S, Hoornaert MT, Martens C, Piessens M, Thierens H, Van der Plaetsen A, Vynckier S. Absorbed dose to water based dosimetry versus air kerma based dosimetry for high-energy photon beams: an experimental study. Phys Med Biol. 2002 Feb 7;47(3):421-40. doi: 10.1088/0031-9155/47/3/305. PMID: 11848121.
3. Barret A, Dobbs J, Morris S, Roques T. Practical Radiotherapy Planning, Fourth Edition, London, England; 2009:10-85
4. Khan MF. The Physics of Radiation Therapy, Fourth Edition. Minneapolis, Minnesota; 2010:5-67
5. Dutreix A. et al. Monitor unit calculation for high energy photon beams, Physics for Clinical Radiotherapy, Belgium; 1997:48-132
6. Almond PR, Biggs PJ, Coursey BM, Hanson WF, Huq MS, Nath R, Rogers DW. AAPM's TG-51 protocol for clinical reference dosimetry of high-energy photon and electron beams. Med Phys. 1999 Sep;26(9):1847-70. doi: 10.1118/1.598691.
7. International Atomic Energy Agency, Technical Report Series No. 398. Absorbed Dose Determination in External Beam Radiotherapy. An International Code of Practice for Dosimetry Based Standards of Absorbed Dose to Water, IAEA, Vienna; 2000:3-180
8. International Commission on Radiation Units and Measurements. Dosimetry of High-Energy Photon Beams Based on Standards of Absorbed Dose to Water, ICRU Report Nr. 64, Bethesda, MD. ICRU. 2000:1-450
9. Ahnesjö A. Collapsed cone convolution of radiant energy for photon dose calculation in heterogeneous media. Med Phys. 1989 Jul-Aug;16(4):577-92. doi: 10.1118/1.596360. PMID: 2770632.
10. Telhaj E, Rrakaqi B, Elezaj Nj, Kaçiu Y,Imeri i Kadolli A, Comparison of IMRT techniques for head and neck cancer treatments based on two different mathematical algorithms Anisotropic analytical algorithm and convolution/superposition. International Scientific Journal. Science. Business. Society.2025;10(1):5-8
11. Xhafa B, Telhaj E, Selimi F, Kaçiu Y, Elezaj N, Rrakaqi B. Utilizing the VMAT Technique for Treating Head and Neck Cancer with Fixed Collimator Jaws. International Journal of Biomedicine. 2024;14(3):474-477. doi:10.21103/ Article14(3)_OA14.
12. Telhaj E, Rrakaqi B, Xhafa B, Elezaj N, Kaçiu Y. Algorithmical Applications in the XiO Treatment Plan Based on Dosimetric Measurements. International Journal of Biomedicine. 2024;15(1):162-166. doi:10.21103/Article15(1)_OA18
13. Nordstrom F. Quality Assurance in Radiotherapy. London University, Malmo, 2012.
14. European Society for Therapeutic Radiology and Oncology. Monitor Unit Calculation for High Energy Photon Beams, Practical Examples, Booklet No.3. Belgium, 2001.