Cone beam computed tomography and image registration based on target area for stereotactic body radiation therapy of lung cancer

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ABSTRACT

This paper aims to compare the dosimetric parameters of the original plan and the simulated plan to explore the clinical value of cone beam CT and planned CT image registration based on the target area. The results showed that Dmax, Dmin, dmean and V60 of PTV in the original plan were (108.3 ± 1.1)%, (97.2 ± 0.3)%, (102.6 ± 0.6)% and (95.2 ± 0.6)% respectively. The Dmax of spinal cord was (9.6 ± 1.8) gV, the V20 of lung was (5.2 ± 1.9)%, and the dmean of lung was (−3.7 ± 1.5) gV; however, when the target area was translated in the three directions of the patient’s back, right side and foot, the dosimetric parameters of the target area (Dmax, Dmin and V60), dmean and V20 of lung and Dmax of spinal cord showed slight differences, which all met the limit requirements of target area and dangerous organs (OARs) (RTOG) 0915 report. Therefore, target based image registration is feasible. If the registration translation error is less than or equal to 1 cm, there is no need to re move the treatment bed according to the registration error.

1. Introduction

When Stereotactic Body Radiation Therapy (SBRT) is used in lung cancer radiotherapy, the tumor local control rate can reach 80–90% (Nagata et al., 2011; Nagatay & Matsuo, 2005; Onishi et al., 2004), which achieves the treatment effect equivalent to surgery. The characteristics of SBRT treatment mode are less treatment time and high single dose, which requires high positioning accuracy; otherwise, it will cause large-dose distribution deviation and seriously affect the treatment effect. However, for patients with lung cancer, due to the influence of respiratory movement, body position fixation, skin traction change, and other factors, it is easy to cause large positioning error and poor repeatability (D’Souza et al., 2007; Hof et al., 2009; Richter et al., 2008; Wu et al., 2008). Image Guided Radiation Therapy (IGRT) is usually used to verify and correct the position and to reduce the treatment error.

When Cone Beam Computed Tomography (CBCT) is used for image-guided radiotherapy, if the pattern for image registration of CBCT and planning Computed Tomography (planning-CT) is based on bone markers or outer contours, it is easy to cause deviation (off-target) between the actual PTV of patients and the PTV in the planning-CT images, thus affecting the therapeutic effect. According to the positioning error and tumor displacement, Wu et al. (Jun & Clinical, 2016; Matsuo et al., 2012; Maxwell et al., 2018; G. Wang et al., 2017; Wu et al., 2013) used skin markers, bone markers, and soft tissue three methods. The dose distribution of the tumor was simulated by using the tumor method and gross method, respectively. Some studies on fixation devices or respiratory control methods aim to reduce the range of motion of the target area, and some studies hope to keep the target area within the irradiation range from the aspect of dynamic tracking of the target area during the treatment process. The above studies are all from the dose distribution or treatment methods, and there is no method to reduce the dose distribution deviation caused by Planning Target Volume (PTV) deviation.

However, this paper proposed that in the image registration process of CBCT and original plan CT, only PTV was used as the registration basis, and the bone markers or contour position deviation caused by the deviation were ignored. The clinical value of this image registration method was studied by evaluating the difference of dosimetric parameters between PTV and Organs At Risk (OARs) with PTV deviation of 1 cm as the boundary.

2. Materials and methods

2.1. Case selection

In this study, we randomly selected 10 patients who received SBRT in our hospital from August 2020 to September 2020, including 5 males and 5 females, aged 30–60 years, with a median age of 45 years. Table 1 depicts the tumor distribution characteristics of the patients. All patients have clear indications for
radiotherapy and receive radiotherapy for the first time, and the informed consent form is signed by the patients or their authorized persons.

2.2. CT scanning and delineation of target area and OARs

All patients were placed in a supine position and fixed with thermoplastic phantom. The patients were scanned with 16 rows of 70 cm large aperture CT. The thickness and distance of the scanning layer were 2.5 mm. The CT images were transmitted to ECLIPSE 13.5 through Varian aria network. According to International Commission on Radiological Units (ICRU) Report No. 50 (Matsuo et al., 2012) and report No. 60 (Maxwell et al., 2018), radiotherapy physicians in our hospital delineated the target area and OARs.

2.3. Planning design

Using Varian ECLIPSE 13.5 Treatment Planning System (TPS), both Intensity Modulated Radiation Therapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT) were designed for each patient, and the layout of fields can be seen in Figure 1. Other design conditions are as follows: the prescription dose is 60 Gy/time, the dose calculation algorithm is Anisotropic Analytical Algorithm (AAA), the dose rate of IMRT is 400, Monitor Units (MU)/min, and the dose rate of VMAT is 0–600MU, the dose distribution of the target area requires 60 Gy to cover more than 95% of the PTV, the dose received by OARs should meet the requirements of Radiotherapy Tumor Group (RTOG) 0915 report.

2.4. Plan evaluation

PTV of each patient is normalized that 95% of PTV receives 99% of the prescription dose. The evaluation parameters of PTV include: the max dose of PTV (PTV- D max), the minimal dose of PTV (PTV- D min), the mean dose of PTV (PTV- D mean), Volume covered by 60 Gy (V 60), Conformal Index (CI), and Homogeneity Index (HI); the CI equation (Bragg et al., 2002; Liu et al., 2004; Mundt et al., 2002; Riet & Mak, 1997) is expressed by

\[
CI = \frac{V_{1,ref}}{V_t} \frac{V_{t,ref}}{V_{ref}},
\]

where \( V_t \) stands for the target volume, \( V_{t,ref} \) stands for the target volume surrounded by a reference isodose surface, \( V_{ref} \) is the volume of all areas surrounded by a reference isodose surface. Here, CI ranges from 0 to 1, and higher CI values indicate better conformity. The HI equation (Chen et al., 2020; Jang et al., 2008; Larraga-Gutierrez et al., 2014; Zhu et al., 2020) is expressed by

\[
HI = \frac{D_3 - D_{98}}{D_p} \times 100\%.
\]

where \( D_3 \) and \( D_{98} \) (doses received by 2% and 98% of the volume, respectively) are the metrics for minimum and maximum doses. \( D_p \) is the prescription dose. Here, HI ranges from 0 to 1 and lower HI values indicate superior dose homogeneity of the target volume.

The evaluation parameters of OARs include: \( D_{max} \) of Spinal Cord (Spinal-Cord- D max), \( V_{20} \) of lung (Lung- V 20), the \( D_{mean} \) of lung (Lung- D mean), and \( D_{mean} \) of heart (Heart- D mean). Among them, \( V_{20} \) represents the volume covered by 2000cGy of the lung.

2.5. Effect of target deviation on dose distribution

First, the PTV of each patient was translated 0.5 cm and 1 cm to the right back, and foot of the patient in the original CT image (can be seen in Figure 2), and

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**Table 1. Tumor distribution characteristics of patients.**

| Patient label | Tumor location | Tumor volume/cm³ |
|---------------|---------------|-----------------|
| 1             | LLL           | 23.6            |
| 2             | RLL           | 19.8            |
| 3             | RLL           | 52.3            |
| 4             | RUL           | 18.5            |
| 5             | RLL           | 16.4            |
| 6             | LUL           | 39.3            |
| 7             | LLL           | 42.2            |
| 8             | LML           | 28.3            |
| 9             | RML           | 21.7            |
| 10            | RUL           | 54.2            |

Notes: LUL = upper lobe of the left lung; LML = middle lobe of the left lung; LLL = lower lobe of the left lung; RUL = upper lobe of the right lung; RML = middle lobe of the right lung; LLL = lower lobe of the right lung.

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**Figure 1.** Layout of fields in the IMRT plan (Left) and VMAT plan (Right).
the treatment isocenter was synchronized by 0.5 cm and 1 cm according to the displacement direction of the tumor. Under the condition that other conditions remain unchanged, we re-optimize and calculate the original plan and obtain six newly simulation plans, and then compare the dosimetric parameters of these six plans with the original plan parameters. Figure 3 is a comparison chart of 95% of the prescribed dose at the same CT level before and after PTV translation.

2.6. Statistical analysis

A statistical analysis was implemented using the IBM SPSS Statistics 19.0 software package. Tested by the Shapiro–Wilk method, data conforming to the normal distribution and measurement data are described by the mean ± standard deviation, and the differences between groups are described by the paired t-test; for the data that do not conform to the normal distribution, the differences between the groups are by the paired signed rank Z test. Test level $\alpha = 0.05$ (two-tailed), $P < 0.05$ means the difference is statistically significant.

3. Results

From the table 2, we can get that $PTV_{D_{\text{max}}}$, $PTV_{D_{\text{min}}}$, $PTV_{D_{\text{mean}}}$, and $V_{60}$ of the target zone in the original plan (plan before translation) are $(108.3 \pm 1.1)\%$, $(97.2 \pm 0.3)\%$, $(102.6 \pm 0.6)\%$, and $(95.2 \pm 0.6)\%$; but after the target area is translated in the three directions of the patient’s back, right, and feet, the target dosimetric parameters ($D_{\text{max}}$, $D_{\text{min}}$ and $V_{60}$) have little change, and all Meet the limit requirements for the target area in the RTOG-0915 report. Among them, $PTV_{D_{\text{max}}}$ is statistically significant when PTV is translated from 0.5 cm to 1 cm to the back; $PTV_{D_{\text{max}}}$ is statistically significant when PTV is translated from 1 cm to the right; PTV is translated from 0.5 cm to the
foot at 1 cm, PTV_Dmax was statistically significant. 

Figure 4 is a comparison of the original plan and the Dose-Volume Histogram (DVH) when the PTV is shifted 1 cm to the right. It can also be seen from the figure

Table 2. Comparison of PTV parameters between the original plan and the six simulated plans.

| Plan     | D_max  | P   | D_min  | P   | D_mean | P   | V_R0  | P   | C1    | H1    |
|----------|--------|-----|--------|-----|--------|-----|-------|-----|-------|-------|
| Original | 108.3 ± 1.1 | 0.001 | 97.2 ± 0.3 | 0.015 | 102.6 ± 0.6 | 0.012 | 95.2 ± 0.6 | 0.008 | 0.81 ± 0.03 | 0.12 ± 0.02 |
| I_0.5 cm | 110.1 ± 1.3 | 0.016 | 98.4 ± 1.4 | 0.037 | 105.7 ± 1.7 | 0.024 | 94.5 ± 2.3 | 0.006 | 0.664 ± 0.008 | 0.12 ± 0.01 |
| I_1.0 cm | 112.4 ± 2.7 | 0.010 | 98.3 ± 2.1 | 0.051 | 105.6 ± 2.9 | 0.012 | 92.4 ± 6.1 | 0.005 | 0.726 ± 0.006 | 0.12 ± 0.02 |
| R_0.5 cm | 109.8 ± 2.5 | 0.024 | 98.4 ± 0.8 | 0.013 | 105.5 ± 1.2 | 0.029 | 93.3 ± 5.6 | 0.007 | 0.731 ± 0.007 | 0.15 ± 0.01 |
| R_1.0 cm | 112.1 ± 2.8 | 0.028 | 98.6 ± 3.1 | 0.021 | 105.7 ± 2.8 | 0.010 | 90.3 ± 7.7 | 0.005 | 0.827 ± 0.006 | 0.13 ± 0.01 |
| P_0.5 cm | 110.1 ± 1.8 | 0.028 | 97.2 ± 0.3 | 0.051 | 104.7 ± 1.5 | 0.014 | 91.3 ± 1.7 | 0.006 | 0.803 ± 0.006 | 0.12 ± 0.01 |
| P_1.0 cm | 112.5 ± 2.8 | 0.031 | 97.6 ± 1.3 | 0.036 | 105.5 ± 1.3 | 0.021 | 92.3 ± 2.9 | 0.013 | 0.793 ± 0.006 | 0.12 ± 0.02 |

Figure 3. Dose distribution of the original plan and simulated plan.

Figure 4. Comparison of DVH between the original plan and simulated plan. Notes: The triangular curve represents R1.0 plan, the rectangular curve represents the original plan, the blue curve represents the heart, the green curve represents the lungs, and the red curve represents PTV.
that the changes in the PTV and OARs (including lung and spinal cord) before and after translation are very small.

Table 3 shows the OARs dose parameter table of the original plan and the 6 simulation plans. From the table, we can get that the D$_{\text{max}}$ of the spinal cord in the original plan is (9.6 ± 1.8) Gy, and the V$_{20}$ of both lungs is (5.2 ± 1.9)%). The D$_{\text{mean}}$ of both lungs is (−3.7 ± 1.5) Gy; but after the target area is translated in the three directions of the patient’s back, right, and foot, the changes in the dosimetric parameters (D$_{\text{max}}$, D$_{\text{min}}$, and V$_{50}$) of the target area are also very small, and all meet the limit requirements for organs at risk in the RTOG-0915 report. When PTV shifted from 0.5 cm to the right, Spinal-Cord D$_{\text{max}}$ was statistically significant; when PTV shifted from 1 cm to the right, Spinal-Cord D$_{\text{max}}$ was statistically significant; PTV shifted from 0.5 cm to the foot at 1 cm, Lung V$_{20}$ and Lung D$_{\text{mean}}$ were statistically significant. Figure 5 shows the image registration process of CBCT and planning CT based on the PTV.

To further evaluate the effect of PTV translation on MU and beam-on time (T), we counted the MU and T of 10 patients (Table 4). It can be seen from the table that before PTV translation, the maximum number of treatment hops is 1453 MU, the minimum is 1253 MU, with an average of 1315 MU, and the average treatment time is after 462 s. After PTV translation, the treatment time and the number of treatment hops for each

| Plan     | Spinal-Cord  | Lung        |
|----------|--------------|-------------|
|          | D$_{\text{max}}$/Gy | P value | V$_{20}$/% | P value | D$_{\text{mean}}$/Gy | P value |
| Original | 9.6 ± 1.8    | -         | 5.3 ± 1.9 | -       | −3.7 ± 1.5           | -       |
| I, 0.5 cm| 10.2 ± 2.2   | 0.752     | 5.2 ± 2.7 | 0.472   | 3.8 ± 1.1            | 0.271   |
| I, 1.0 cm| 10.8 ± 2.8   | 0.891     | 5.1 ± 2.3 | 0.382   | 3.7 ± 1.4            | 0.121   |
| R, 0.5 cm| 9.7 ± 2.4    | 0.037     | 5.3 ± 1.2 | 0.398   | 3.9 ± 1.5            | 0.953   |
| R, 1.0 cm| 10.2 ± 3.7   | 0.035     | 5.1 ± 1.8 | 0.425   | 3.8 ± 1.4            | 0.741   |
| P, 0.5 cm| 9.6 ± 1.7    | 0.927     | 5.6 ± 1.7 | 0.017   | 4.2 ± 1.3            | 0.009   |
| P, 1.0 cm| 9.4 ± 1.9    | 0.714     | 5.8 ± 1.9 | 0.012   | 4.4 ± 1.5            | 0.018   |

Figure 5. Image registration process between CBCT and planning CT based on PTV.
Table 4. Comparison of MU and T.

| Evaluation parameter | Original plan | I_0.5 cm | I_1.0 cm | R_0.5 cm | R_1.0 cm | P_0.5 cm | P_1.0 cm |
|-----------------------|---------------|----------|----------|----------|----------|----------|----------|
| MU-max                | 1453          | 1455     | 1448     | 1462     | 1467     | 1457     | 1464     |
| MU-min                | 1253          | 1251     | 1247     | 1243     | 1248     | 1260     | 1254     |
| MU-mean               | 1315          | 1302     | 1324     | 1320     | 1327     | 1302     | 1306     |
| T (s)                 | 462           | 471      | 464      | 481      | 472      | 457      | 455      |

Simulation plan are different. Small changes, but the amplitude of the changes, are all less than 3%, and the changes in the number of treatment jumps and time caused by PTV translation can be ignored.

4. Discussion

In the current treatment process, there are three main methods for registration of CBCT and original CT images before treatment: skin markers, bony markers, and soft tissue registration. Many people have also done different studies to verify the accuracy of each method (Al-Ghamdi, 2019; Yang et al., 2019), and the results are similar. They all believe that the results obtained by bone mark registration and soft tissue registration are quite different, and the use of bone mark registration is more. It is easy to cause the target area to miss the target, but these studies have not verified the pros and cons of each method from the influence of dosimetric distribution. Landry et al. (Landry & Dedes, 2014; Li et al., 2015) used the difference in dose distribution to verify the pros and cons of the three registration methods. The experiment concluded that the soft tissue registration method has less influence on the dose distribution than the bone marker registration method and the skin marker registration method. Miura et al. (Miura et al., 2014; Y. Y. Wang et al., 2010) also studied the GTV shift, but it only simulated the GTV shift and did not translate the treatment center into the GTV. Therefore, they concluded that tumor shift affects the GTV and PTV dose distribution with greater impact. This article is based on the previous research conclusions, that is, the target area is used as the basis for CBCT registration, and the 1 cm range of motion limit is directly given. When the target area deviation is between 0.5 cm and 1.0 cm, the treatment bed is translated into dose distribution. In contrast, 1.0 cm is chosen as the limit because if the error range is greater than 1 cm after the target area is registered, the position setting should be performed again.

The studies in the above documents all use fixed field intensity modulation technology for planning design because the number of radiation fields is limited, the dose distribution will be affected accordingly, and the VMAT technology, and fixed field intensity modulation technology has a certain degree of comparison with VMAT technology disadvantages of VMAT, such as the research results in the literature, prove that for the deviations in the implementation of the plan, such as the deviation of the MLC position, the rack angle, and so on, the impact of VMAT is less than that of the fixed field intensity modulation technology. Other literature (Lohynská et al., 2020; Tang et al., 2021; Ye et al., 2010; Zekiou & Parlar, 2020) reported that for the treatment of prostate patients, VMAT is less affected by the change of the patient’s contour due to the treatment process than the fixed field intensity modulation technique. Therefore, although the position of PTV is shifted in this article, the relative outer contour, lung, spinal cord, etc., are different from the original plan, but the final simulation result is that the dose distribution of PTV and normal tissues can meet the dose distribution requirements.

5. Conclusion

For lung cancer patients receiving SBRT treatment, PTV-based registration is feasible in the image registration process of CBCT and planning CT. If the registration translation error is less than or equal to 1 cm, there is no need to reposition the treatment bed according to the size of the registration error (to ensure the synchronous translation of the treatment isocenter). The dosimetric parameters after registration have little difference from the original plan, which fully meets the requirements of precise treatment.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Ethical compliance

There is no ethics approval required for this paper.

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References

Al-Ghamdi, A. H. (2019). Health risk assessment of natural background radiation in the soil of Eastern province, Saudi Arabia. Journal of Radiation Research and Applied Sciences, 12(1), 219–225. https://doi.org/10.1080/16878507.2019.1637045
Bragg, C. M., Conway, J., & Robinson, M. H. (2002). The role of intensity-modulated radiotherapy in the treatment of parotid tumors. *International Journal of Radiation Oncology, Biology, Physics*, 52(3), 729–738. https://doi.org/10.1016/S0360-3016(01)02660-8

Chen, M. L., Li, X. T., & Wei, Y. Y. (2020). Diagnostic value of spectral CT parameters in differentiating different types of lung cancer. *Journal of Medical Imaging and Health Informatics*, 10(8), 1804–1808. https://doi.org/10.1166/jmihi.2020.3189

D’Souza, W. D., Nazareth, D. P., & Zhang, B. (2007). The use of gated and 4DCT imaging in planning for stereotactic body radiation therapy. *Medical Dosimetry*, 32(2), 92–101. https://doi.org/10.1016/j.meddos.2007.01.006

Hof, H., Rhein, B., & Haering, P. (2009). 4D-CT-based target volume definition in stereotactic radiotherapy of lung tumours: Comparison with a conventional technique using individual margins. *Radiotherapy & Oncology Journal of the European Society for Therapeutic Radiology & Oncology*, 93(3), 419–423. https://doi.org/10.1016/j.radonc.2009.08.040

Jang, S. Y., Liu, H. H., & Mohan, R. (2008). Underestimation of low-dose radiation in treatment planning of intensity-modulated radiotherapy. *International Journal of Radiation Oncology, Biology, Physics*, 71(S), 1537–1546. https://doi.org/10.1016/j.ijrobp.2008.04.014

Jun, L., & Clinical, X.-Z.-Z. (2016). Feasibility of leakage and transmission radiation dosimetry using multileaf collimator of ELEKTA synergy-5 accelerator during conventional radiotherapy. *Journal of Medical Imaging and Health Informatics*, 6(2), 1–7. https://doi.org/10.1166/jmihi.2016.1706

Landry, G., & Dedes, G. (2014). Phantom based evaluation of CT to CBCT image registration for proton therapy dose recalculation. *Physics in Medicine and Biology*, 60(2), 595–613. https://doi.org/10.1088/0033-9152/60/2/595

Larraga-Gutierrez, J. M., Garcia-Garduno, O. A., & Ballesteros-Zebadua, P. (2014). Comparative analysis of several detectors for the measurement of radiation transmission and leakage from a multileaf collimator. *Physica Medica-European Journal Of Medical Physics*, 30 (3), 391–395. https://doi.org/10.1016/j.ejmp.2013.10.006

Li, J., Zhang, X.-Z., Gui, L.-G., Ge, Y., Chen, Y., Tang, X.-B., Chen, D., & Chai, L. (2015). Dosimetric study on treatment planning of the whole central nervous system (CNS) by different radiotherapy. *Journal of Medical Imaging and Health Informatics*, 5(4), 1–5. https://doi.org/10.1166/jmihi.2015.1459

Liu, H. H., Wang, X., Dong, L., Wu, Q., Liao, Z., Stevens, C. W., Guerrero, T. M., Komaki, R., Cox, J. D., & Mohan, R. (2004). Feasibility of sparing lung and other thoracic structures with intensity-modulated radiotherapy for non-small-cell lung cancer. *International Journal of Radiation Oncology, Biology, Physics*, 58(4), 1268–1279. https://doi.org/10.1016/j.ijrobp.2003.09.085

Lohynska, R., Ndllová, A., & Tereza, D. (2020). Haematotoxicity in IMRT/VMAT curatively treated anal cancer. *Klinicka Onkolgie*, 33(4), 288–294. https://doi.org/10.14735/amko202888

Matsuura, Y., Shibuya, K., & Nakamura, M. (2012). Dose-volume metrics associated with radiation pneumonitis after stereotactic body radiation therapy for lung cancer. *International Journal of Radiation Oncology, Biology, Physics*, 83(4), 545–549. https://doi.org/10.1016/j.ijrobp.2012.01.018

Maxwell, O., Adewoyin, O. O., Joel, E. S., Ehi-Eromosele, C. O., & Hassaina, M. (2018). Radiation exposure to dwellers due to naturally occurring radionuclides found in selected commercial building materials sold in Nigeria. *Journal of Radiation Research and Applied Sciences*, 11(3), 225–231. https://doi.org/10.1016/j.jrras.2018.01.007

Miura, H., Masai, N., & Oh, R. J. (2014). Dosimetric impact of tumor position and lung density variations in lung stereotactic body radiotherapy. *International Journal of Medical Physics Clinical Engineering & Radiation Oncology*, 03(1), 43–48. https://doi.org/10.4236/ijjmer.2014.31007

Mundt, A. J., Lujan, A. E., & Rotmensch, J. (2002). Intensity-modulated whole pelvic radiotherapy in women with gynecologic malignancies. *International Journal of Radiation Oncology, Biology, Physics*, 52(2), 1330–1337. https://doi.org/10.1016/S0360-3016(01)02785-7

Nagata, Y., Wulf, J., & Lax, I. (2011). Stereotactic radiotherapy of primary lung cancer and other targets: Results of consultant meeting of the international atomic energy agency. *International Journal of Radiation Oncology, Biology, Physics*, 79(3), 660–669. https://doi.org/10.1016/j.ijrobp.2010.10.004

Nagatay, T. K., & Matsuo, Y. (2005). Clinical outcomes of a phase I/II Study of 48 Gy of stereotactic body radiotherapy in 4 fractions for primary lung cancer using a stereotactic body frame. *International Journal of Radiation Oncology, Biology, Physics*, 63(5), 1427–1431. https://doi.org/10.1016/j.ijrobp.2005.05.034

Onishi, H., Nagata, Y., & Shirato, H. (2004). Stereotactic hypofractionated high-dose irradiation for patients with stage I non-small cell lung carcinoma: Clinical outcomes in 241 cases of a Japanese multi-institutional study. *Cancer*, 101(7), 1623–1631. https://doi.org/10.1002/cncr.20539

Richter, A., Baier, K., & Meyer, J. (2008). Influence of increased target dose inhomogeneity on margins for breathing motion compensation in conformal stereotactic body radiotherapy. *Medical Physics*, 8(1), 1–15. https://doi.org/10.1116/1756-6649-8-5

Riet, A. V., & Mak, A. C. (1997). A conformation number to quantify the degree of conformity in brachytherapy and external beam irradiation: Application to the prostate. *International Journal of Radiation Oncology, Biology, Physics*, 37(3), 731–736. https://doi.org/10.1016/S0360-3016(96)00601-3

Tang, Z., Zhao, G., & Ouyang, T. (2021). Two-phase deep learning model for short-term wind direction forecasting. *Renewable Energy*, 173(72), 1005–1016. https://doi.org/10.1016/j.renene.2021.04.041

Wang, G., Wang, Y., & Liu, Y. (2017). Fast and robust segmentation of individual tooth crown from cone beam computed tomography images. *Journal of Medical Imaging and Health Informatics*, 7(2), 355–363. https://doi.org/10.1166/jmihi.2017.2059

Wang, Y. Y., Fu, X. L., & Xia, B. (2010). Impact of different anatomical landmarks on registration in imaging-guided radiation for lung cancer. *Chinese Journal of Radiation Oncology*, 19(6), 517–519. https://doi.org/10.3760/cma.j.issn.1004-4221.2010.06.011

Wu, J., Betzing, C., & He, T. T. (2013). Dosimetric comparison of patient setup strategies in stereotactic body radiation therapy for lung cancer. *Medical Physics*, 40(5), 15–19. https://doi.org/10.1118/1.4801926

Wu, J., Li, H., & Shekhar, R. (2008). An evaluation of planning techniques for stereotactic body radiation therapy in lung tumors. *Radiotherapy and Oncology*, 87(1), 35–43. https://doi.org/10.1016/j.radonc.2008.02.010
Yang, Q., Zhou, W., & Li, J. (2019). Comparative analysis of diagnostic value for shear wave elastography and real-time elastographic imaging for thyroid nodules. *Journal of Medical Imaging and Health Informatics, 9*(2), 334–338. https://doi.org/10.1166/jmihi.2019.2594

Ye, J., Rao, M., & Chen, F. (2010). Evaluation of the dosimetric impact of intrafraction motion and MLC leaf interplay in hypofractionated prostate IMRT and VMAT treatment. *International Journal of Radiation Oncology, Biology, Physics, 78*(3), 378. https://doi.org/10.1016/j.ijrobp.2010.07.891

Zekiolu, A., & Parlar, U. (2020). Investigation of awareness level concerning radiation safety among healthcare professionals who work in a radiation environment. *Journal of Radiation Research and Applied Sciences, 14*(1), 1–8. https://doi.org/10.1080/16878507.2020.1777657

Zhu, Y., Hu, B., & Tumor-Specific Nascent, X. L. (2020). Nine-peptide-epitopes prediction and bioinformatics characterization in human colorectal cancer. *Journal of Medical Imaging and Health Informatics, 10*(6), 1338–1345. https://doi.org/10.1166/jmihi.2020.3018