

Stereotactic radiotherapy treatment of lymph nodes in oligometastatic prostate neoplasm: evaluation of the positioning setup

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ABSTRACT

Prostate cancer is one of the main male neoplasms and can present in oligometastatic form, characterized by the presence of a limited number of metastases. In this context, stereotactic body radiotherapy (SBRT) represents an effective therapeutic option, capable of delaying the use of prolonged systemic treatments such as hormone therapy. The retrospective observational study, conducted at the AOU of Alessandria, evaluated the reproducibility of the positioning of patients undergoing lymph node SBRT by the use of lower and upper limb immobilization systems. 34 patients with oligometastatic prostate cancer were included, for a total of 206 fractions treated. Positioning errors were detected by daily CBCT images, analyzing translational and rotational displacements along the three axes. The results show an average of translational errors between 0.27 and 0.36 cm and rotational errors between 0.71° and 1.31°, with generally low values. The DIST metric, a three-dimensional positioning accuracy index, showed an average of 0.64 cm, indicative of good reproducibility. The greatest variations were observed in rotations, suggesting the need for further optimization of devices and treatment margins. The conclusions underline the effectiveness of the positioning systems used and the importance of continuous training and systematic monitoring of errors to improve the accuracy of radiotherapy treatment. The study also suggests the opportunity to customize margins and upgrade technology systems to further optimize clinical outcomes.

INTRODUCTION

Prostate cancer is the second most commonly found cancer in men, with an estimated 1.4 million diagnoses worldwide [1]. In Italy it is the first form of male neoplasia with more than 40,000 new cases per year, and represents 18.5% of the total number of cancers. It is also the third most mortality [2]. The likelihood of developing it increases with age and is considered very rare under the age of 50.

Since it is a slow-growing neoplasm, there is a high possibility of making an early diagnosis, especially through screening which includes: urological examination and dosage of prostate-specific antigen (PSA), an organ marker, not a specific tumor that can be elevated even in the case of prostatitis or benign prostatic hypertrophy [3].

Ultrasound-guided prostate biopsy is considered the gold standard for diagnosis.

Multiparametric magnetic resonance imaging allows a better diagnosis of the extent of the disease, especially about the overcoming of the capsule; The neoplasm is often multifocal and tends to spread via the lymphatic and blood routes [4].

The therapeutic approach to localized disease includes surgery (radical prostatectomy) or radiotherapy

considered primary treatment [5].

The treatment of metastatic prostate cancer at onset or distant recurrence after primary therapy has been enriched over the years with more options beyond the classic androgen blockade, particularly in oligometastatic neoplasia, a metastatic tumor still subject to radical therapy and not only palliative [6,7]. In this context, radiotherapy can play an important role in both the control of the primary tumor and oligometastases.

In the last decade, new clinical entities defined as oligometastases or oligorecurrences have been proposed, widely accepted among specialists in the field. Oligometastatic patients are those who have 1-5 metastatic sites associated with an active primary lesion, oligorecurrent patients differ in having the primary tumor under control [5].

The oligometastatic situation seems to benefit from both local and systemic therapies [8].

Oligometastatic prostate cancer at diagnosis is a heterogeneous disease in which the stratification of patients by disease burden is an essential factor.

In the case of a number of metastases not exceeding 3, whether they are lymph nodes or bones, radical radiotherapy is recommended aimed at both the pri-



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mary and the metastatic sites to be associated with androgen deprivation [9].

In the context of a multimodal treatment, the role of stereotactic body radiotherapy (SBRT) is increasingly consolidated: an innovative non-invasive radiotherapy technique that allows a high dose of radiation to be administered directly to the tumor volume with extreme accuracy and precision, causing cell death [10].

As this is a high-precision therapy with a high dose gradient, precision in patient positioning is crucial. The best positioning setup is established during simulation CT scans and then replicated at each session. The position must be comfortable, reproducible and such that it does not interfere with the orientation of the irradiation beams. Therefore, the correct choice and configuration of the immobilization device is essential.

In case of incorrect positioning of the patient, situations of underdose of the tumor target and overdose of healthy structures and organs at risk could occur resulting in increased acute and late toxicities or other undesirable side effects [11].

The aim of the study is to evaluate the reproducibility of the positioning of patients in stereotactic radiotherapy treatment of lymph nodes from oligometastatic prostate neoplasia.

The objectives of the study were:

a) To evaluate the reproducibility of the positioning of oligometastatic prostate neoplasm lymph nodes in patients undergoing stereotactic radiotherapy.

b) To evaluate errors in the setup of patients undergoing stereotactic radiotherapy treatment of lymph nodes from oligometastatic prostate cancer

2. Materials and Methods

A retrospective observational study was conducted at the Complex Structure of Radiation Oncology of the University Hospital of Alessandria. The study was approved by the Ethics Committee and conducted in compliance with the ethical principles outlined in the Declaration of Helsinki.

34 patients with oligometastatic prostate cancer with pelvic lymph node involvement and treated with stereotactic body radiation therapy (SBRT) were randomly enrolled between January 2021 and January 2025. Inclusion criteria included 18 years of age or older, the presence of 1–5 pelvic lymph node metastatic sites confirmed by advanced imaging, and the availability of comprehensive radiotherapy treatment data. Patients with incomplete treatment cycles or missing CBCT data were excluded.

During stereotactic radiotherapy treatment of lymph nodes in oligometastatic prostate cancer, Civco's Combifix and Wing Board immobilization devices were used.

The Combifix allows the setup of the lower limbs.

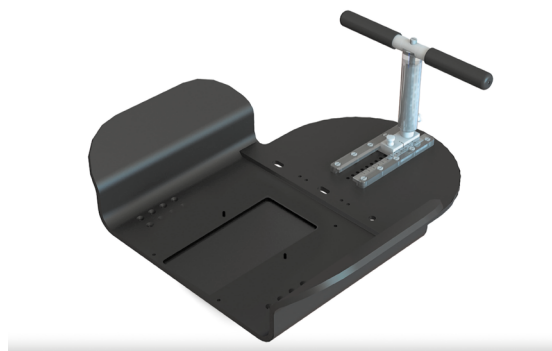
The system consists of a Polyvinyl Chloride (PVC) base on which a cushion for the support of the feet (with variable angle) and a cushion for the support

of the knees can be fixed with a support to make it taller. The distance between these two cushions is adjustable to suit the patient's height (Fig. 1).



Fig. 1 Combifix

The Wing Board allows the setup of the upper limbs: the Acrylonitrile Butadiene Styrene (ABS) support involves the use of head cushions of different shapes and sizes in order to be more adherent to the patient's head and a dumbbell adjustable in distance and height to be able to stop the hands outside the volume of the body (Fig. 2).



The Cone Beam Computed Tomography (CBCT) and HEXAPOD platform were used to record daily positioning errors. Displacements were classified as: translational (X, Y, Z in centimeters) and rotational (Pitch, Roll, Yaw in degrees).

The Distance metric (DIST), a composite index, was used to assess the three-dimensional accuracy of the placement.

Before each treatment, daily CBCT images were acquired and compared with simulation computed tomography (CT). During this process, translational (in centimeters) and rotational (in degrees) deviations along the x, y, and z axes were detected and documented. Patients were positioned using the same setup used during the previous computed tomography (CT) scan.

Descriptive statistics were used to synthesize patient demographic characteristics and positioning errors. The mean, standard deviation, interquartile intervals, and maximum values were calculated. The DIST metric was determined as the Euclidean norm of translational errors, in order to provide an overall index of three-dimensional positioning accuracy. All

analyses were performed using SPSS software, version 25. The level of statistical significance has been set at $p \leq 0.05$

34 patients were included. The median age was 79 years. All had histologically confirmed prostate adenocarcinoma with lymph node metastases.

RESULTS

Considering the X, Y and Z axes, the averages of the observed displacements [table 1], which have the meaning of systematic error, are 0.27 0.36 0.32 cm for translations and 1.31 0.71 0.82 for rotations, the standard deviations (indicative of random error) are 0.22 0.34 0.33 for translations and 0.95 0.68 0.67 for rotations. Interquartile values range from a minimum of 0, when no variations were needed, to a maximum of 2.9 cm (for translations) or 2.9° (for rotations) which are the maximum values allowed for correction. There has never been a case of having to repeat the positioning or cancel the session. The DIST value uses the three translation values and returns a single parameter dependent on the entire trio, thus becoming representative of an overall value: three low translations will give a low value indicative of a good positioning. We measured an average of 0.64 with a standard deviation of 0.40.

DISCUSSION

The translations show the need to correct the posi-

tion of a value that is on average around 3 mm in all directions with the same standard deviation.

Near-zero shifts are a good sign, indicating that the patient’s positioning system is substantially optimal. Rotations show larger variations, especially along the X-axis. This could be due to variations in inter-fraction or intrafraction.

The variations indicated by the standard deviation highlight that there are cases in which the patient is not perfectly aligned before correction, in particular those of rotations. indicate that better positioning may be needed.

Even the DIST value, indicative of the overall displacement of the isocenter, which takes the value between 0 and 5.2 expresses a substantially high precision of the positioning activity (Fig. 3.).

The retrospective design of the present study has some limitations, including the impossibility of collecting detailed anthropometric data. Body size is known to influence the reproducibility of immobilization systems; In particular, parameters such as pelvic circumference have been identified as critical factors. Previous studies [12,13] have shown that patients with a pelvic circumference greater than 105 cm or with obesity may present with less positional stability, especially along the mid-lateral axis. In addition, even with the same pelvic circumference, body conformation can vary significantly between individuals, affecting separations on the anterior-posterior and medio-lateral axes.

Table 1. Metriche errore di posizionamento.

Asse	Mean translational error (cm) ± SD	Average rotational error (°) ± SD
X	0.27 (± 0.22)	1.31 (± 0.95)
Y	0.36 (± 0.34)	0.71 (± 0.68)
Z	0.32 (± 0.33)	0.82 (± 0.67)

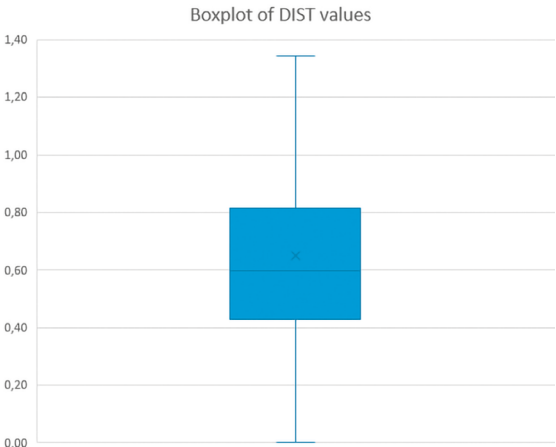


Fig.3 Boxplot of DIST values



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CONCLUSIONS

The analysis of the data shows some significant variations to be paid attention to within a global context of very precise positioning.

Indications for the improvement of results must include continuing to record and analyze positioning data to identify patterns and to provide feedback and continuous training to technical personnel for constant and continuous improvement of performance.

First of all, each immobilization device has its own

strengths, such as the reduction of setup errors in a particular axis. After determining the strengths and weaknesses, modifications or even combinations of the systems could be used in order to achieve better immobilization.

Secondly, customised margins for each axis, or even for each direction, were essential to tailor the PTV. Personalised margins should be considered in the future [11].

In addition, the possibility of implementing technological resources by updating both imaging systems and immobilization devices, integrating with the collection of biometric data, can be evaluated.

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