Control of the position of the spinal canal during head and neck radiotherapy

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Head and neck cancers are often located near an important anatomical structure such as the spinal cord, brain stem, etc., making the treatment difficult. The primary method of treating head and neck tumors is surgery, often combined with pre-or postoperative radiotherapy. Patients have been irradiated approximately 30 fractions, depending on the dosage. The correct patient position during radiotherapy is crucial for its effectiveness of radiotherapy. During the reconstruction of the patient's position, the spine tends to some rotation in the cervicothoracic section in relation to the reference CT. These studies focused on head and neck cancers, particularly the doses absorbed in the canal and spinal cord. This research aimed to check whether the stabilization and verification of the patient's position are sufficient to make a treatment plan correctly and safely during radiotherapy. It has been assessed by comparing the dose distribution in the spinal canal calculated in the TPS Treatment Planning System based on CT and the distribution of the dose delivered during the treatment and calculated based on the CT-CBCT fusion.

MATERIALS AND METHODS

30 Patients were randomly selected from the group and treated for head and neck cancers using IMRT or VMAT techniques, with a total dose not exceeding 72 Gy and a fractional dose not exceeding 2.4 Gy. According to the clinical protocol, the maximum dose in the spinal cord structure must not exceed the point value of 45 Gy. 926 CBCT images were analyzed for spinal canal mobility. To verify the reproducibility of the treatment plan, a rigid fusion CT was performed with all CBCT scans. For the study, it was assumed that the movement of the core is analogous to the spinal canal, and its possible another movements are negligible. In each of the analyzed patients, the structures of the spinal canal were transferred from CBCT to CT, and the dose distribution was subsequently calculated in the Eclipse TPS system Fig.1. This resulted in a dose that was approximately obtained by the spinal canal in a single therapeutic session. After summing up the individual fractions, the amount received by the spinal canal during the entire treatment was estimated. Due to the observation of local changes in the shape of the spinal canal, its structure was divided into four parts on CBCT and CT Fig.2. The purpose of this division was to assess in which region the most significant changes occur, both in the position of structure and in the received dose.

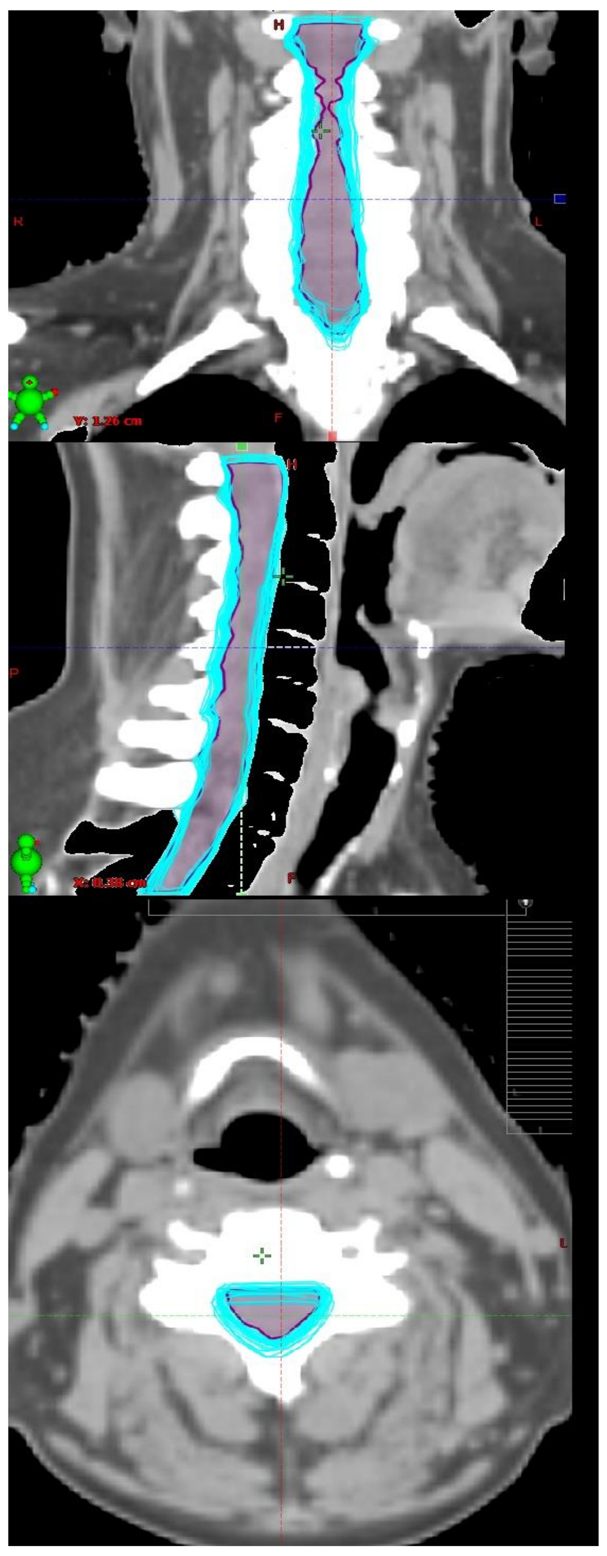

Fig.1. Frontal, sagittal and transverse CT of the patient. Transferred structures from CBCT are marked in blue. The contours represent the position of the spinal canal during each fraction. The position of the canal on the CT images taken before the first radiotherapeutic session is marked in purple

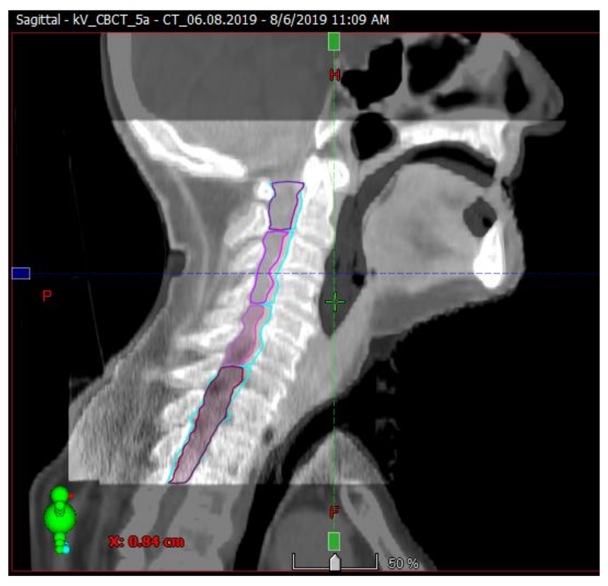

Fig. 2: Division of the vertebral canal into segments.

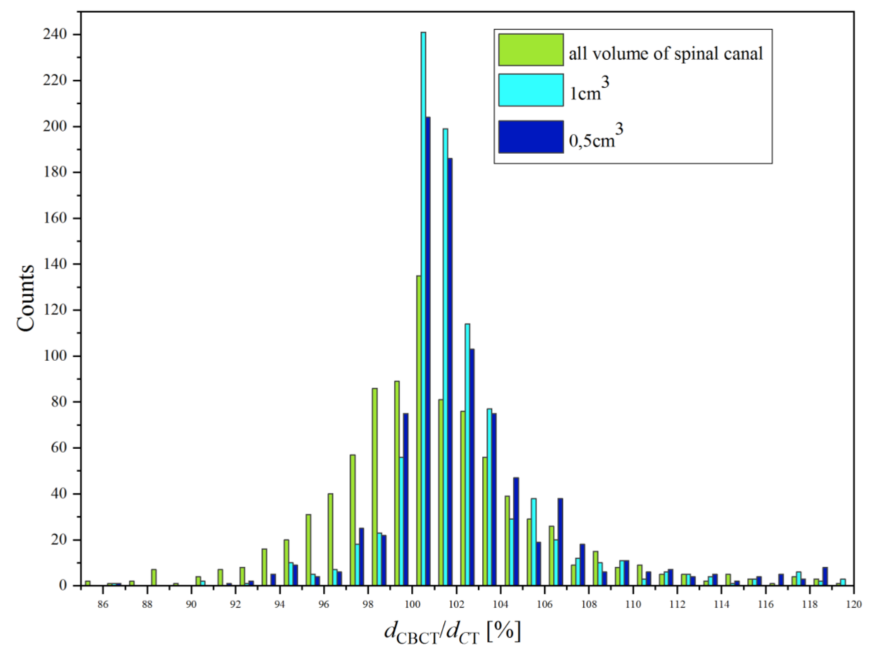

Fig.3. Histogram of the ratio of fractional doses obtained in points and in the volume of the spinal canal - 1 cm3 and 0.5 cm3. The total number of counts for a single volume is 926

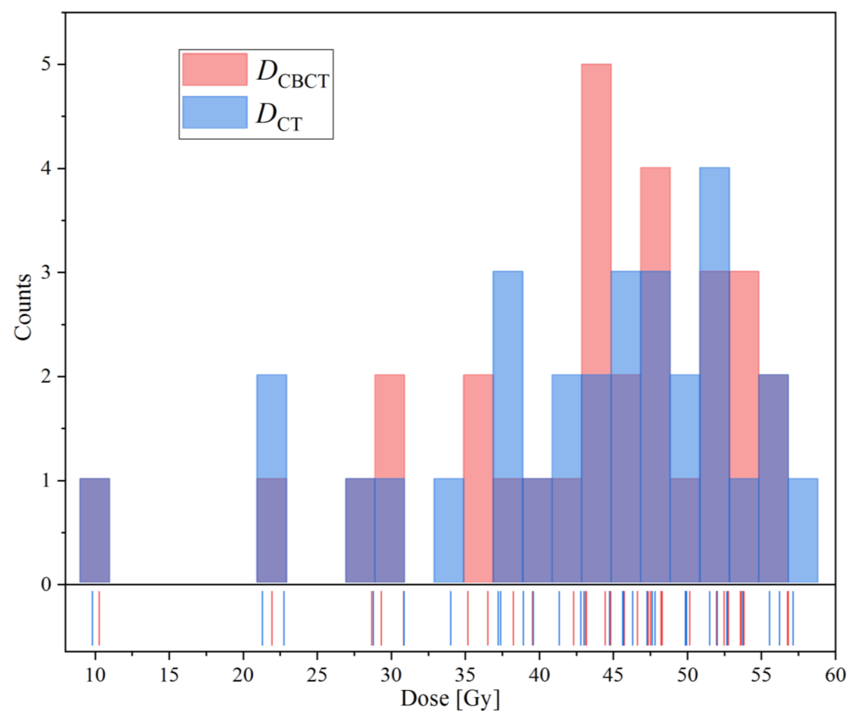

Fig.4. Comparison of the sum of doses (in the spinal canal) planned and delivered - summed up for each patient separately

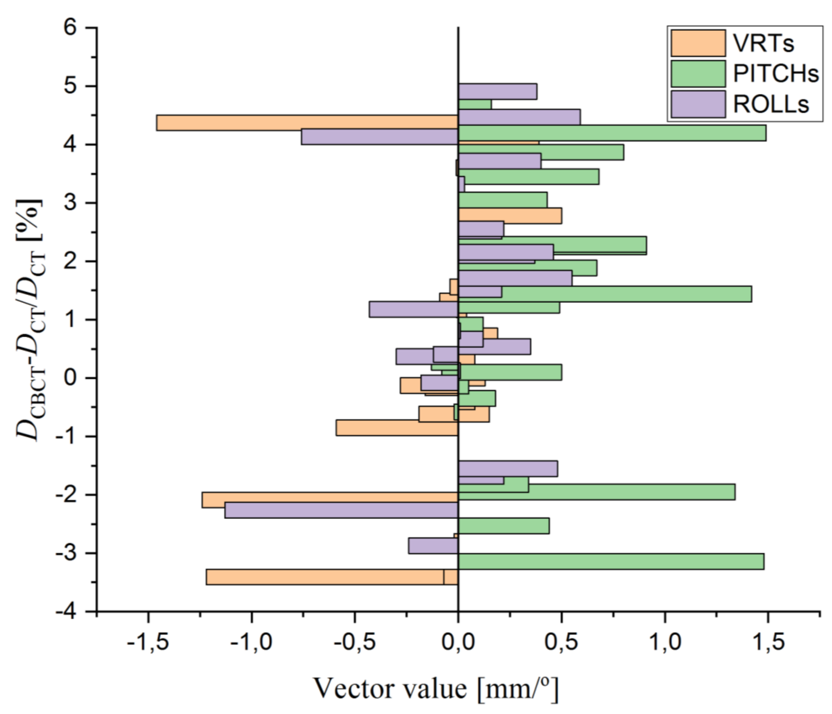

Fig.6. Dependence of the relative difference of DCT and DCBCT on mean values of position shift vectors.

RESULTS AND DISCUSSION

Based on DVH, the doses received by the entire spinal canal were determined, as well as the maximum values of fractional doses of 0.5 cm3 and 1 cm3 of his volumes. Based on all collected fractions, the ratio between the estimated fractional dose was calculated based on CBCT images (dCBCT) and the planned fractional dose based on CT (dCT). The obtained results are presented in Fig. 3. DCT was the maximum point dose in the spinal canal in the original treatment plan. DCBCT was obtained by summing up the maximum doses delivered by each fraction. The doses' standard deviation and their absolute and relative differences were calculated for each patient. The p-value of the Student's t-test for the single sample and the population was obtained. The calculated dose distributions are presented in Fig. 4. The percentage difference between the total doses of DCBCT and the planned dose of DCT ranges from - 3.14% to 26.01%, reaching the maximum dose decrease by 1.74 Gy and the maximum increase by 5.92 Gy at the end of radiotherapy treatment. The Student's t-test with a significance level of 5% shows that in 43% of patients, the differences between DCT and DCBCT were not statistically significant. At the same time, based on the same parameter, 17 patients were not irradiated as scheduled. In eight of them, the maximum dose exceeds 45 Gy, but in these patients, a difference (DCBCT - DCT) < 1Gy. It is different for another nine of them (DCBCT - DCT)> 1 Gy throughout treatment. However, for the entire study group, as a result of the Student's t-test, we obtain a value of p = 0.76, which proves that there are no statistically significant differences between the doses and allows (based on the maximum point doses) to define the therapy as a therapy carried out correctly. The mean values obtained for the entire study group are below 45 Gy. The mean of relative difference dose value does not exceed 0.5 Gy, which corresponds 1.8% relative value the difference to the mean DCT. The mean DCT and DCBCT values of 43.29 Gy and 42.8 Gy, respectively, do not indicate a risk of spinal cord injury. Each dose over 45 Gy in the canal (Fig. 5A.) poses a potential risk of damage to the spinal cord. The data presented in Fig. 5B. confirm that the most significant changes in point doses indicate the local nature of the variability of the patient's position. After drawing the spinal cord on each CT and reading the dose planned for it, and adding the corresponding percentage difference calculated for the spinal canal, the doses delivered to the spinal cord were estimated. The obtained values are shown in Fig. 5C. The uncertainties marked in the picture show the percentage differences between the CT and CBCT doses. None of the patients achieved a dose greater than 45 Gy in the spinal cord.

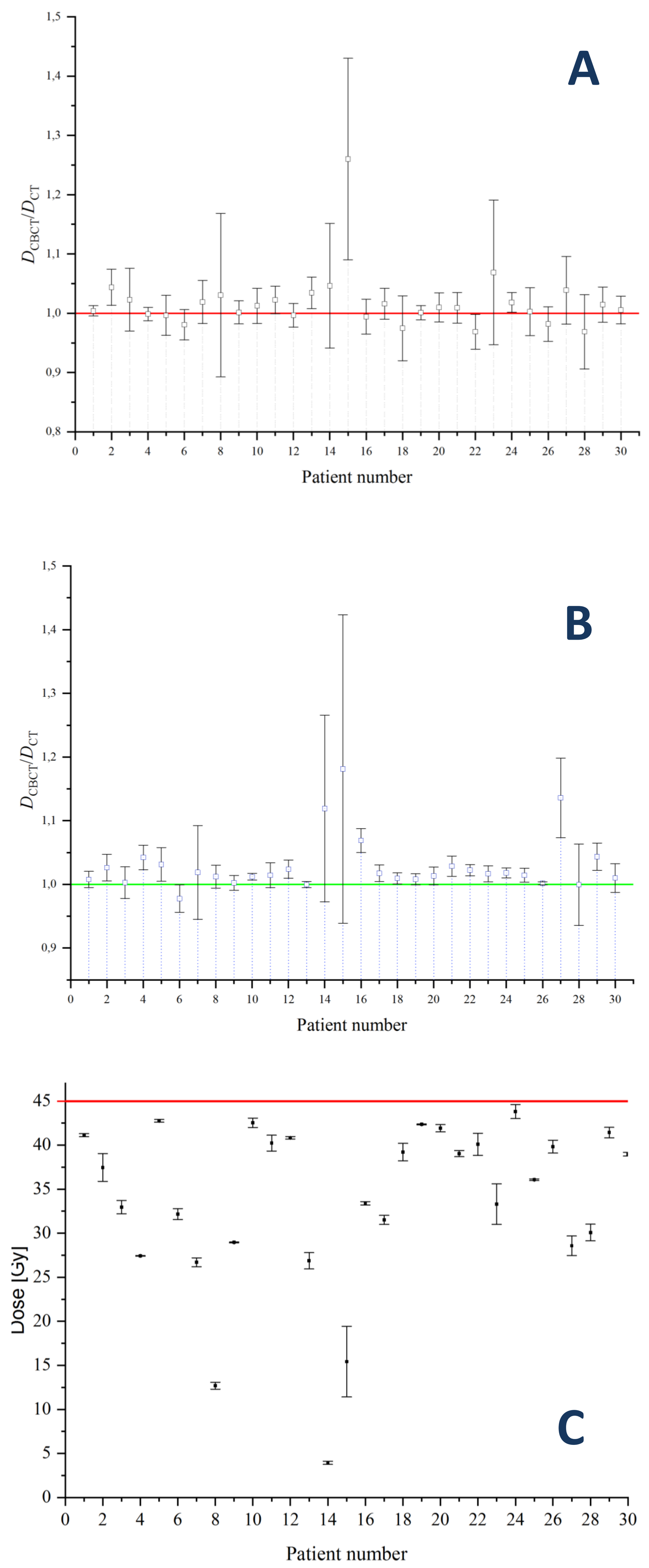

Fig.5. Normalized values of absorbed doses in the spinal canal (A), in its volume of 0.5 cm3 (B), image (C) shows the total doses delivered to the spinal cord. The red line shows the tolerance dose for the core. The calculations were made after all radiotherapeutic fractions were completed and presented for individual patients.

Using the Offline Review tool, it was possible to perform a fusion, in which the values of translation and rotation vectors were averaged over the fractions. The patient's position changed from his position on the tomographic images taken before the first radiotherapy session. The data showed that if (DCT - DCBCT) <0.65 Gy in the canal, the DCT does not differ statistically from DCBCT, and when the average PITCH vector value for a patient exceeds 0.5 °, DCBCT is statistically different from DCT. Most frequently exceeding the value of | 0.5 mm | / | 0.5 ° | vectors are VRT translation and PITCH rotation. In ten patients, the mean PITCH value exceeded 0.5 °, of which five patients exceeded the value of 1 °. Six patients had a mean VRT value exceeding 0.5 mm, including four patients exceeding 1 mm. High values of these shifts indicate the patient's mobility in the directions observed when the head moves forward and backward and the neck is bent in the "U" shape. The mean value of ROLL rotation exceeds 0.5 °, suggesting that some patients also have problems turning their heads to the left or right. Based on the Polish Society of Medical Physics recommendations, the Student's t-test was performed, the results of which indicate that for the group of patients, all shifts, except for the PITCH rotation, are consistent with the hypothesis that y=0, where y is a given shift-vector. Fig. 6. shows the dependence of the relative difference of DCT and DCBCT on the shift vector value. When the value of the DCT - DCBCT difference increases, there is densification or/and an increase in the value of the shifts. The structure of the spinal canal has been divided into four parts. The purpose of this division was to assess in which part the most significant changes occur, both in location and in the received dose. The same steps as for the undivided structure were performed. The changes in the maximum point doses in the individual segments were calculated. The intersection of the segment structure on CT and CBCT was determined and compared with the volume on CT. This allows an assessment of how much the segment volume has changed relative to its position before administering the first therapeutic fraction. The obtained results showed that the most significant changes in the spinal canal arrangement occur in the C3-C4 segment. Larger dose changes were also recorded in the same area.

CONCLUSION:

Planning and verification of the correctness of the treatment were performed correctly. The maximum doses in the volumes of 0.5 cm3 and 1 cm3 showed less variability. Despite the positioning errors and dose differences, the spinal cord was not at risk in any patient. There was no close correlation between the dose change value and the value of the translation or rotation vectors. However, a concentration of positioning errors was observed. These shifts may be partly related to the tilting of the head back and the bending of the neck towards the radiation source. The lack of correlation suggests the presence of additional factors, such as muscle tension, weight loss, or random errors. Particular attention should be paid to the ability of the patient to maintain the appropriate position throughout the duration of the fractional dose.