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Planning Head and Neck radiotherapy with endovenous contrast in CT: viability for AAA and AcurosXB

Planejamento de Radioterapia de Cabeça e Pescoço com Contraste Endovenoso em CT: viabilidade para AAA e AcurosXB

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Abstract

Background and purpose: many radiotherapy services execute two computed tomography (CT) scans for the treatment of head and neck (H&N) tumors: with (contrast CT) or without contrast (non-contrast CT), for target volume delineation and dose calculation, respectively. However, performing two CT scans brings problems such as unnecessary exposure of the patient to radiation and errors in CT image fusion. Therefore, the objective of this study was to verify the possibility of performing only the contrast CT as the routine for dose calculation with AAA and AcurosXB. Materials and methods: contrast and non-contrast CT scans from 77 patients were retrospectively analyzed, and the Hounsfield Unit (HU) values of the target volume and some organs at risk (as well as dosimetric values were evaluated and compared). Statistical analysis was performed by calculating the intraclass correlation coefficient (ICC), assuming a significance level of 5%. Results: there is a correlation between the values obtained for both HU and dosimetric data between the CT scans since the ICC was close to 1 and the p-value was lower than 0.05 for all cases. Conclusion: our data indicates that it is possible to perform only the contrast CT in the simulation routine to treat patients with head and neck tumors.

Keywords: *Radiotherapy; Computed tomography; Contrast Agent; Dose Calculation; AAA; AcurosXB; VMAT; IMRT*

Resumo

Introdução e objetivo: muitos serviços de radioterapia realizam duas tomografias computadorizadas (CT) para o tratamento de tumores de cabeça e pescoço (H&N): com (CT com contraste) ou sem contraste (TC sem contraste), para delineamento do volume alvo e cálculo da dose, respectivamente. No entanto, a realização de duas tomografias traz problemas como exposição desnecessária do paciente à radiação e erros na fusão das imagens de CT. Portanto, o objetivo deste estudo foi verificar a possibilidade de realizar apenas a CT contrastada como rotina para cálculo de dose com AAA e AcurosXB. Materiais e métodos: foram analisadas retrospectivamente CTs com e sem contraste de 77 pacientes e avaliados e comparados os valores da Hounsfield Unit (HU) do volume-alvo e de alguns órgãos em risco (bem como os valores dosimétricos). A análise estatística foi realizada por meio do cálculo do coeficiente de correlação intraclasse (ICC), assumindo nível de significância de 5%. Resultados: existe uma correlação entre os valores obtidos tanto para HU quanto para os dados dosimétricos entre as tomografias, pois o ICC foi próximo de 1 e o valor p foi menor que 0,05 para todos os casos. Conclusão: nossos dados indicam que é possível realizar apenas a CT contrastada na rotina de simulação para tratar pacientes com tumores de cabeça e pescoço.

Palavras-chave: Radioterapia; Tomografia computadorizada; Agente de contraste; Cálculo de Dose; AAA; AcurosXB; VMAT; IMRT

1. Introduction

Cancer is characterized by uncontrolled cell growth that stops responding to physiological regulation, leading to tumor formation. Tumor cells can establish only a primary tumor. Still, in some cases, it can migrate through the extracellular matrix and invade blood circulation, setting new tumor sites in a process called metastasis. Since 2000, the world has progressed in fighting against noncommunicable diseases (NCDs) (1). Yet, a 2016 estimation shows that these diseases were responsible for 71% of the overall deaths, 22% by cancer (2). Cancer deaths have grown by 37% in the last two decades, according to a 2021 estimation (1). In Brazil, according to National Cancer Institute (INCA), the most frequent cancer in the past few years were non-melanoma skin cancer, followed by prostate cancer and breast cancer (3).

Head and neck cancer is an aggressive and lethal disease, the sixth most common cancer with over 500,000 annually reported cases, being the third deadliest cancer worldwide (4). The most common H&N cancer is squamous cell carcinoma, usually appearing in the oropharynx, oral cavity, hypopharynx, or larynx due to environmental factors combined with genetic inheritance, besides other important risk factors like alcoholism and smoking (5–7). In the last decades, the human papillomavirus (HPV) was identified as another critical risk factor responsible for about 25% of the tumors detected in this anatomic site (4).

There are several treatment options for H&N cancer, including chemotherapy, radiotherapy, immunotherapy, gene therapy, and photodynamic therapy (8). Given the inherent toxicity of RT, this therapy requires specific protocols before radiation is delivered to the patient. First, the patient is submitted

to a simulation, where the patient is immobilized with particular devices designed for each anatomic site to be treated so that the patient's movements are reduced. This procedure will guarantee reproducibility for further daily treatments, where the patient is positioned precisely in the same way, reducing setup errors (9).

After choosing the best patient setup, a Computed Tomography (CT) scan can be performed. The obtained image will be the reference for radiotherapy planning used by the radio-oncologist for delineating organs at risk (OAR) and planning target volume (PTV) processes. For better precision in structure delineation, contrast agents must be used to enable better tissue differentiation. The X-rays attenuation of each voxel can be represented by Hounsfield Units (HU), HU = $(\mu - \mu_w)/ \mu_w$, where μ and μ_w are linear attenuation coefficients of tissue and water, respectively. In Treatment Planning System (TPS), the dose calculation is based on the conversion of HU into photon attenuation, atomic composition, and mass density (10).

Conventionally, two CT scans are performed for treating H&N patients: with and without endovenous contrast application. RT dose calculation is based on the images from non-contrast CT since endovenous contrast can introduce errors in dose calculation (11,12) due to changes in HU generated by radiopaque material inserted. However, contrasted images improve OAR delineation by radiation oncologists.

After target volume definition, starts the choice and insertion of multiple fields in TPS to reach the maximum possible conformations, sparring healthy regions. The dose necessary to treat the PTV and dose limits to OARs is defined and evaluated by clinical protocols like Radiation Therapy Oncology Group (RTOG) documents.

For treatment delivery, the patient is positioned at the linear accelerator couch through coordinates acquired in the CT scan and using the same accessories defined in the simulation. For dose calculation, the CT from each patient is analyzed using specific algorithms applied to photons, giving the dose distribution. The two used algorithms are Analytical Anisotropic Algorithm (AAA) and Acuros XB, both integrated into the Eclipse Treatment Planning (Varian Medical Systems, Palo Alto, CA).

Analytical Anisotropic Algorithm (AAA) is a kernel-based convolution/superposition calculation method applied to photons dose calculation. It considers tissue heterogeneity near the interaction point and corrects for heterogeneity by executing density scaling Monte Carlo derived kernel for homogeneous medium (13). Dose calculation is performed through convolution models of primaries photons, scattered electrons by accelerator structure, and scattered photons (14). The clinical beam is discretized in small beams of finite size, called beamlets, which apply convolutions of photons and electrons. The superposition of these convolutions provides the final dose distribution.

Acuros XB solves the LBTE (linearized Boltzmann transport equation) by numerical methods explicitly, and it is a convergent method, which means that sufficient fine adjustments will converge to a solution of the LBTE. The objective of explicit LBTE solution methods development was generated as an alternative for time-consuming Monte Carlo simulations. In Eclipse, Acuros XB realizes four steps (13,15,16): transport of source model fluency into the patient, calculation of scattered photon fluence in the patient, calculation of scattered electron fluence in the patient, and dose calculation, that supports reporting dose to medium or dose to water.

Using two CT scans, with and without contrast, could cause errors in image registration due to the time gap between images acquisition and an additional and unnecessary patient radiation exposition. Using only contrast CT to OARs determination and dose calculation is an alternative to minimize these errors. Still, it is necessary to verify the dosimetric impact by studying dose variations in OAR and PTV, along with the presence of HU and dose calculation correspondence between the two CT scans.

This is a retrospective study of H&N cancer patients treated with radiotherapy using Intensity Modulated Radiation Therapy (IMRT) or Volumetric Modulated Arc Therapy (VMAT) subject to CT scans with and without contrast at the Barretos Cancer Hospital. This work aims to compare differences in dose calculation and the correlation between the two types of CT scans using AAA and AcurosXB algorithms. The findings obtained in this study will allow the change planning routine of these cases, bringing the possibility of performing only one CT scan for H&N patients.

2. Methods and materials

2.1 Data collection

Data from 77 patients with H&N cancer who had acquired CT scans with and without contrast and were treated with IMRT or VMAT were selected to verify CT scan correspondence. Data from 2016 to 2018 were collected from the planning system database, EclipseTM (Varian Medical Systems, Palo Alto, CA). All patients were treated at the Barretos Cancer Hospital, and before data assessment, the study was submitted to Ethics Committee Approval (CAAE 00411318.0.0000.5437). The prescribed dose was performed based on RTOG 0615 (17), 0022 (18), and 1216 (19) for conventional fractionation and the Hypno Trial of the International Atomic Energy Agency (IAEA) for hypofractionation(20). The prescription changed for each patient, considering the tolerance limits of each organ or tissue around the tumor region. Target volume doses ranged from 52.00 Gy to 69.96 Gy.

2.2 Planning and dose calculation

Plan optimization and calculation were performed in contrast to CT (C) scans. For dosimetric evaluation between both CT scans, fluency generated in this optimization was copied and applied to CT images

without contrast (NC), allowing the plan without contrast to be calculated in the same conditions as the plan with contrast. This procedure reproduces the purpose of this study by performing dose calculations in CT images with contrast but delivering the dose to the patient without contrast since the patient will not receive any contrast during the treatment. Dose calculations were performed in EclipseTM TPS (Varian Medical Systems, Palo Alto, CA) version 13.7, using AAA and AcurosXB algorithms for dose calculation and Photon Optimizer (PO) algorithm for optimization.

The contrast applied in patients is composed of 300 mg of iodine for mL of contrast, 75 and 100 mL injected intravenously for patients up to 75 Kg and > 75 kg, respectively.

2.3 Comparative analysis of CT scans

For comparative analysis between CT scans, parotids (right and left), spinal cord, and PTV were selected. The compared parameters were: mean HU values, mean dose to the structure (Dmean), minimum received dose for the volume of 98% (D98), 95% (D95), 2% (D2) of PTV, mean dose (Dmean) for right (R) and left (L) parotids and maximum dose for the spinal cord.

The sample was calculated based on the difference between doses before and after contrast addition, considering the test for the averages of paired samples. Based on this calculation, the statistical analysis Intraclass Correlation Coefficient (ICC) was employed to verify the agreement between the obtained results. ICC estimates and their 99% confidence intervals were calculated using SPSS v.21.0 (SPSS Inc, Chicago, IL) based on mean-rating (k=2), absolute agreement, and two-way mixed effects model. For the null hypothesis (H0), it was considered that CT scans with and without contrast are not different from each other. All the analyses and the graphics were performed in SPSS v.21.0.

2.4 Ethical aspects

The Barretos Cancer Hospital Ethics Committee approved this work, and it is under all required ethical aspects present at 466/2013 Resolution (ANVISA, Brazil). The CAAE number for this project is 00411318.0.0000.5437.

3. Results

Data from 77 patients were retrospectively collected, and the average HU of all selected structures (PTV, spinal cord, and parotids) were collected for both CTs: with and without contrast. A mean HU value with standard deviation was obtained for each CT and each structure. The difference between HU value in both CTs for each structure were also calculated for each patient and obtained an average of this data (average difference of mean HU) shown in Table 1. Median, minimum, and maximum values were related to the average difference of mean HU.

In the same way, dosimetric evaluation was performed, and the dose coverage, maximum dose, and mean dose for PTV were observed along with the received dose for organs at risk for AAA (Table 2) and AcurosXB (Table 3). Further, we analyzed the correlation of CT scans through QQ-plot analysis of contrast (C) x non-contrast CT (NC) scan. ICC values and confidence interval corresponding to each structure are depicted in Figures 1, 2, and Supplementary Figure 1.

Figures 1 and 2 show QQ-plots correlating data from contrast (C), and non-contrast CT (NC) scans for all structures, using AAA and AcurosXB algorithms. In Figure 1, PTV D98, D95, and D2 show statistical agreement analysis for dosimetric comparison between both CTs for the 77 patients. Both axis, ordinate and abscissa, are given in Gy, representing the raw values and not just the dose difference.

Table 1. HU mean comparison: contrast and non-contrast CT.

Structures	Average of mean HU (Standard Deviation)		Average difference of mean HU	Median	Minimum	Maximum
	Contrast	*Non-contrast*				
PTV	27.32 (53.93)	5.50 (51.93)	22.91	21.30	4.10	62.69
Spinal Cord	52.34 (16.63)	45.36 (10.26)	7.56	4.48	0.02	85.95
R Parotid	42.84 (27.65)	11.90 (23.17)	30.94	31.05	11.79	55.86
L Parotid	41.28 (28.71)	10.09 (24.70)	31.20	30.70	14.25	53.98

Source: The Author (2022).

Table 2. Dosimetric comparison: contrast and non-contrast CT(AAA).

Structures	Absolute mean dose (Standard Deviation)(Gy)		Absolute mean dose difference (Gy)	Median	Minimum	Maximum
	Contrast	Non-contrast				
PTV (D98)	58.52 (5.63)	58.17 (5.62)	0.58	0.30	0.01	2.42
PTV(D95)	59.63 (5.69)	59.55 (5.70)	0.29	0.17	0.00	2.97
PTV(D2)	65.21 (6.30)	65.23 (6.50)	0.30	0.16	0.01	10.20
PTV(Dmean)	62.31 (5.93)	62.41 (5.87)	0.22	0.11	0.00	3.17
Spinal Cord (Dmax)	35.15 (4.46)	35.62 (4.37)	0.65	0.19	0.00	9.18

Parotid R (Dmean)	27.49 (8.96)	27.29 (8.87)	0.69	0.22	0.00	6.55
Parotid L (Dmean)	26.68 (8.78)	26.54 (8.70)	0.51	0.22	0.00	3.62

Source: The Author (2022).

4. Discussion

Considering the stages of the radiotherapy treatment process, two main parameters should be influenced by the use of contrast agents: delineation and dose calculation. Delineation for PTV is improved by contrast using CT performed for treatment simulation. On the other hand, dose calculation can be affected by density changes in CT due to higher attenuation of the contrasted tissues when compared to the density of the tissue without contrast (21–23).

Upon HU means comparison, it is possible to verify clearly that HU values of contrasted CT are higher than HU values of non-contrast CT scan for all structures due to kV radiation that is more absorbed by contrasted tissues. Another critical point is that despite the HU average differences being numerically high, this is not so relevant since the HU range generally goes from -1000 to 1000, so a maximum difference of 85.95, in the spinal cord case, does not contribute significantly to the dose calculation in our dataset. In Supplementary Figure 1, the ICC is greater than 0.9 for PTV, which indicates excellent agreement and between 0.60 and 0.74 for OARs, which shows good agreement. Despite this, analyzing the confidence intervals, it is possible to see that this result is not significant. In other words, we can´t accept the null hypothesis, and both CTs can be considered different from each other related to HU values. This is expected since the contrast agent is used to modify the HU value providing better differentiation between structures in CT.

Table 3. Dosimetric comparison of CT with and without contrast (AcurosXB)

Structures	Absolute mean dose (Standard Deviation)(Gy)		Absolute mean dose difference (Gy)	Median	Minimum	Maximum
	Contrast	Non-contrast				
PTV (D98)	57.79 (5.43)	57.41 (5.45)	0.59	0.29	0.01	4.47
PTV(D95)	59.04 (5.57)	58.92 (5.65)	0.40	0.16	0.00	4.01
PTV(D2)	65.07 (6.34)	65.24 (6.32)	0.19	0.13	0.00	1.03
PTV(Dmean)	62.01 (5.83)	62.07 (5.84)	0.13	0.09	0.00	0.85
Spinal Cord (Dmax)	34.86 (4.39)	35.11 (4.36)	0.53	0.21	0.00	5.61
Parotid R (Dmean)	27.07 (8.84)	27.14 (8.97)	0.66	0.24	0.01	5.84
Parotid L (Dmean)	26.64 (8.73)	26.27 (8.65)	0.90	0.32	0.01	12.29

Source: The Author (2022).

Concerning the dosimetric impact, one of the most relevant points in this work, it is expected that if the dose value for contrast CT scan is increased, the value for non-contrast CT scan increases proportionally, indicating agreement between them. Thus, the closer the dots get to the solid line, the better agreement between data, as can be seen in Figures 1 and 2. ICC greater than 0.90 indicates excellent reliability. ICC for PTV and organs at risk dose parameters were greater than 0.9, as all its confidence intervals mean an excellent agreement between CT scans related to dose calculation. Furthermore, p-values for dosimetric data for PTV coverage and organs at risk were all inferior to 0.05, which indicates strong evidence in favor de H0, which means that contrast and non-contrast CT scans are not different from each other.

The differences in absolute dose mean for all structures are close to zero. The maximum difference value was 12.29 Gy for parotid left calculated with AcurosXB. Still, when the means and median differences are compared, the results show that the median differences are smaller than the mean differences, indicating that only a few points are distant from the ideal, which can be seen in Figure 2. Choi et al. reported that the CT range of 30 HU values for cartilage and soft tissues results in a dose difference of less than 1% (12), agreeing with the results obtained in this work.

Considering the different algorithms employed, there was no significant influence in dose calculation due to the use of contrast agents in CT scans, corroborating previously published data for head and neck (12), esophagus (24) (25), lungs (26), and pancreas (23). Ramm et al. and Shibamoto reported how the applied contrast could influence dose calculation. They demonstrated a decrease in the influence by increasing the number of fields used in planning (10,23,27). This observation is under the data of this work that used modulated treatment techniques in several fields that did not suffer the influence of contrast agents. Then, even for calculation with algorithms with distinct characteristics, both can be used for dose calculation in CT images with contrast without harm to the patient by implementing the institution's endovenous contrast administration protocols with the considered calculation algorithms.

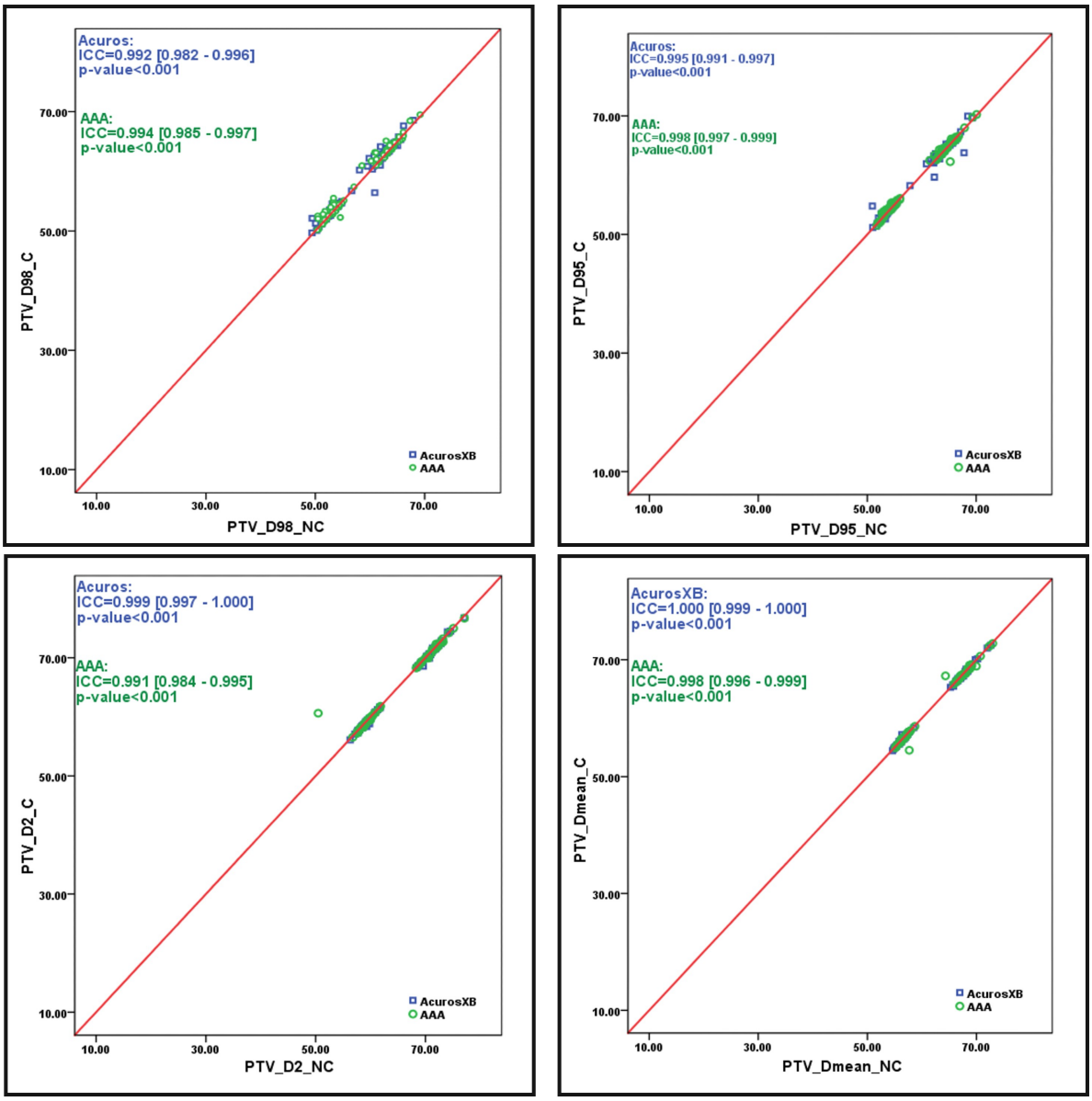

Figure 1. Dosimetric comparison for delivered dose in PTV volume calculated with AcurosXB and AAA in both CT, with and without CT contrast.

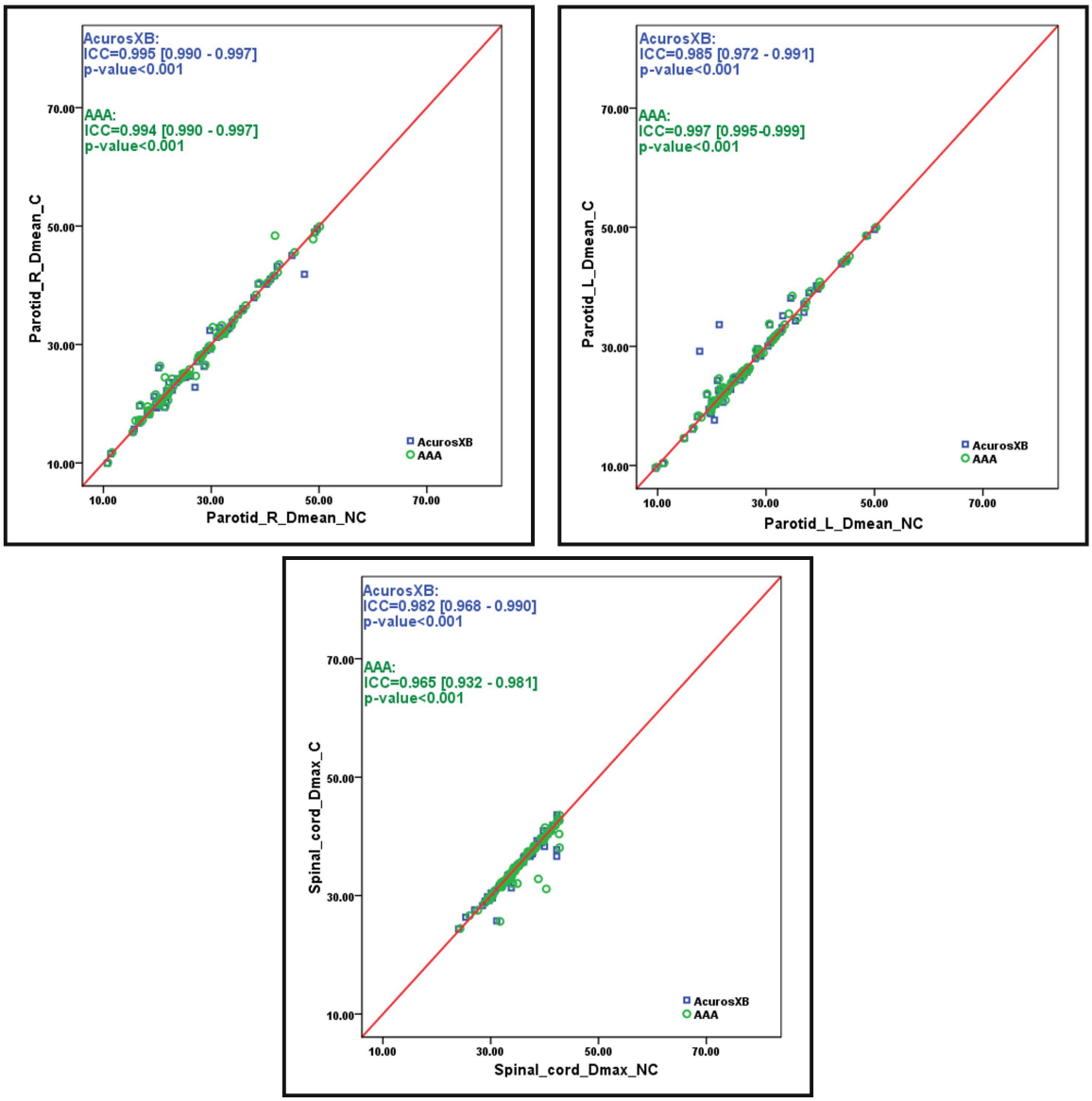

Figure 2. Dosimetric comparison for delivered dose in OAR volume calculated with AcurosXB and AAA in both CT, with and without CT contrast.

5. Conclusions

Considering the ICC and confidence intervals, we can see that there are differences between HU values for both CTs, but this doesn´t impact dose calculation. The ICC values are greater than 0.9 for dosimetric analyses, so it is possible to confirm that we can accept the null hypothesis and assume that there is no difference between dose calculation in CT with or without contrast. The confidence intervals also have values greater than 0.9. The p-values lower than 0.05 point to strong evidence in favor of H0. This result is independent of the calculation algorithm (AAA or AcurosXB).

Therefore, it is feasible to use contrast CT scans for dose calculation, regardless of which of the two algorithms will be used, since the dose distribution is reproducible in treatment planning and in agreement with published results. Thus, it is possible to perform only one CT for treatment simulation. This is a relevant finding, considering the reduction of procedures submitted to the patient during RT treatment.

It is essential to consider that the results presented in this work depend on the contrast protocol used in our institution and on the algorithms and TPS employed. We can´t guarantee the same for others contrast protocols or TPS, which can be considered a weak work point. So, we encourage the performance of new analyses with others contrast protocols and TPS if needed to confirm reliability for new configurations.

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Conflict Interest Statement

The authors declare no conflicts of interest.

Data availability statement

The corresponding author's data supporting this study's findings are available upon reasonable request.

References

1. WHO WHO. World Heath Statistics. 2021. 136 p.
2. WHO. What is cancer [Internet]. 2018 [cited 2021 May 19]. Available from: https://www.who.int/health-topics/cancer#tab=tab_1
3. INCA. INCIDÊNCIA DE CÂNCER NO BRASIl. Vol. 1, Journal of Materials Processing Technology. 2020. 1–8 p.
4. C W, S W, SJ S, N W, J K, H R, et al. HPV - A different view on Head and Neck Cancer. Laryngorhinootologie. 2018 Mar 1;97(S 01):S48–113.
5. Galbiatti ALS, Padovani-Junior JA, Maníglia JV, Rodrigues CDS, Pavarino ÉC, Goloni-Bertollo EM. Câncer de cabeça e pescoço: causas, prevenção e tratamento. Braz J Otorhinolaryngol. 2013;79(2):239–47.
6. Jethwa AR, Khariwala SS. Tobacco-related carcinogenesis in head and neck cancer. Cancer and Metastasis Reviews 2017 36:3. 2017 Aug 12;36(3):411–23.
7. D H, E G, M P, M H, P B. Head and neck cancer prevention: from primary prevention to impact of clinicians on reducing burden. Ann Oncol. 2019 May 1;30(5):744–56.
8. Minicucci EM, Da Silva GN, Salvadori DMF. Relationship between head and neck cancer therapy and some genetic endpoints. World J Clin Oncol. 2014;5(2):93–102.
9. Abreu CECV, Ferreira PPR, Moraes FY de, Neves Jr WFP, Gadia R, Carvalho H de A. Stereotactic body radiotherapy in lung cancer: an update. Jornal Brasileiro de Pneumologia. 2015;41(4):376–87.
10. Ramm U, Damrau M, Mose S, Manegold KH, Rahl CG, Böttcher HD. Influence of CT contrast agents on dose calculations in a 3D treatment planning system. Phys Med Biol. 2001 Oct;46(10):2631–5.
11. Liauw S, Amdur R, Mendenhall W, Palta J, Kim S. The Effect of Intravenous Contrast on Intensity-Modulated Radiation Therapy Dose Calculations for Head and Neck Cancer. Am J Clin Oncol. 2005 Nov 1;28:456–9.
12. Choi Y, Kim JK, Lee HS, Hur WJ, Hong YS, Park S, et al. Influence of intravenous contrast agent on dose calculations of intensity modulated radiation therapy plans for head and neck cancer. Radiotherapy and Oncology. 2006;81(2):158–62.
13. Yan C, Combine AG, Bednarz G, Lalonde RJ, Hu B, Dickens K, et al. Clinical implementation and evaluation of the Acuros dose calculation algorithm. J Appl Clin Med Phys. 2017;18(5):195–209.
14. Sievinen J, Ulmer W, Kaissl W. AAA photon dose calculation model in Eclipse. Palo Alto (CA): Varian Medical Systems. 2005;Varian doc:1–23.
15. Gregory A. Failla, Todd Wareing, Yves Archambault ST. Acuros XB advanced dose calculation for the Eclipse treatment planning system.
16. Seniwal B, Bhatt CP, Fonseca T. Comparison of dosimetric accuracy of acuros XB and analytical anisotropic algorithm against Monte Carlo technique. Biomed Phys Eng Express. 2020 Jan 31;6.
17. Lee NY, Zhang Q, Pfister DG, Kim J, Garden AS, Mechalakos J, et al. Addition of bevacizumab to standard chemoradiation for locoregionally advanced nasopharyngeal carcinoma (RTOG 0615): A phase 2 multi-institutional trial. Lancet Oncol. 2012 Feb;13(2):172–80.
18. Eisbruch A, Harris J, Garden AS, Chao CKS, Straube W, Harari PM, et al. Multi-Institutional Trial of Accelerated Hypofractionated Intensity-Modulated Radiation Therapy for Early-Stage Oropharyngeal Cancer (RTOG 00-22). Int J Radiat Oncol Biol Phys. 2010 Apr;76(5):1333–8.
19. Le QT, Jordan R, Bauman JE, Blvd H. NRG ONCOLOGY RTOG 1216 RANDOMIZED PHASE II/III TRIAL OF SURGERY AND POSTOPERATIVE RADIATION DELIVERED WITH CONCURRENT CISPLATIN VERSUS DOCETAXEL VERSUS DOCETAXEL AND CETUXIMAB FOR HIGH-RISK SQUAMOUS CELL CANCER OF THE HEAD AND NECK [Internet]. Available from: www.rtog.org
20. Jacinto AA, Batalha Filho ES, Viana LDS, de Marchi P, Capuzzo RDC, Gama RR, et al. Feasibility of concomitant cisplatin with hypofractionated radiotherapy for locally advanced head and neck squamous cell carcinoma 11 Medical and Health Sciences 1112 Oncology and Carcinogenesis. BMC Cancer. 2018 Oct 23;18(1).
21. Fenchel S, Fleiter TR, Aschoff AJ, van Gessel R, Brambs HJ, Merkle EM. Effect of iodine concentration of contrast media on contrast enhancement in multislice CT of the pancreas. British Journal of Radiology. 2004;77(922):821–30.
22. Engeroff B, Kopka L, Harz C, Grabbe E. [Impact of different iodine concentrations on abdominal enhancement in biphasic multislice helical CT (MS-CT)]. Rofo. 2001 Oct;173(10):938–41.
23. Zhu F, Wu W, Zhu F, Wang Y, Wang Y, Xia T. Influence of computed tomography contrast agent on radiotherapy dose calculation for pancreatic carcinoma: A dosimetric study based on tomotherapy and volumetric-modulated arc therapy techniques. Med Dosim. 2017;42(4):317–25.
24. Tian JM, Shen YH, Yang XW, Liang SA, Shan L, Li HL, et al. Antifungal cyclic peptides from Psammosilene tunicoides. J Nat Prod. 2010;73(12):1987–92.
25. Li HS, Chen JH, Zhang W, Shang DP, Li BS, Sun T, et al. Influence of intravenous contrast medium on dose calculation using CT in treatment planning for oesophageal cancer. Asian Pac J Cancer Prev. 2013;14(3):1609–14.
26. Shi W, Liu C, Lu B, Yeung A, Newlin HE, Amdur RJ, et al. The effect of intravenous contrast on photon radiation therapy dose calculations for lung cancer. Am J Clin Oncol. 2010 Apr;33(2):153–6.
27. Shibamoto Y, Naruse A, Fukuma H, Ayakawa S, Sugie C, Tomita N. Influence of contrast materials on dose calculation in radiotherapy planning using computed tomography for tumors at various anatomical regions: a prospective study. Radiother Oncol. 2007 Jul;84(1):52–5.

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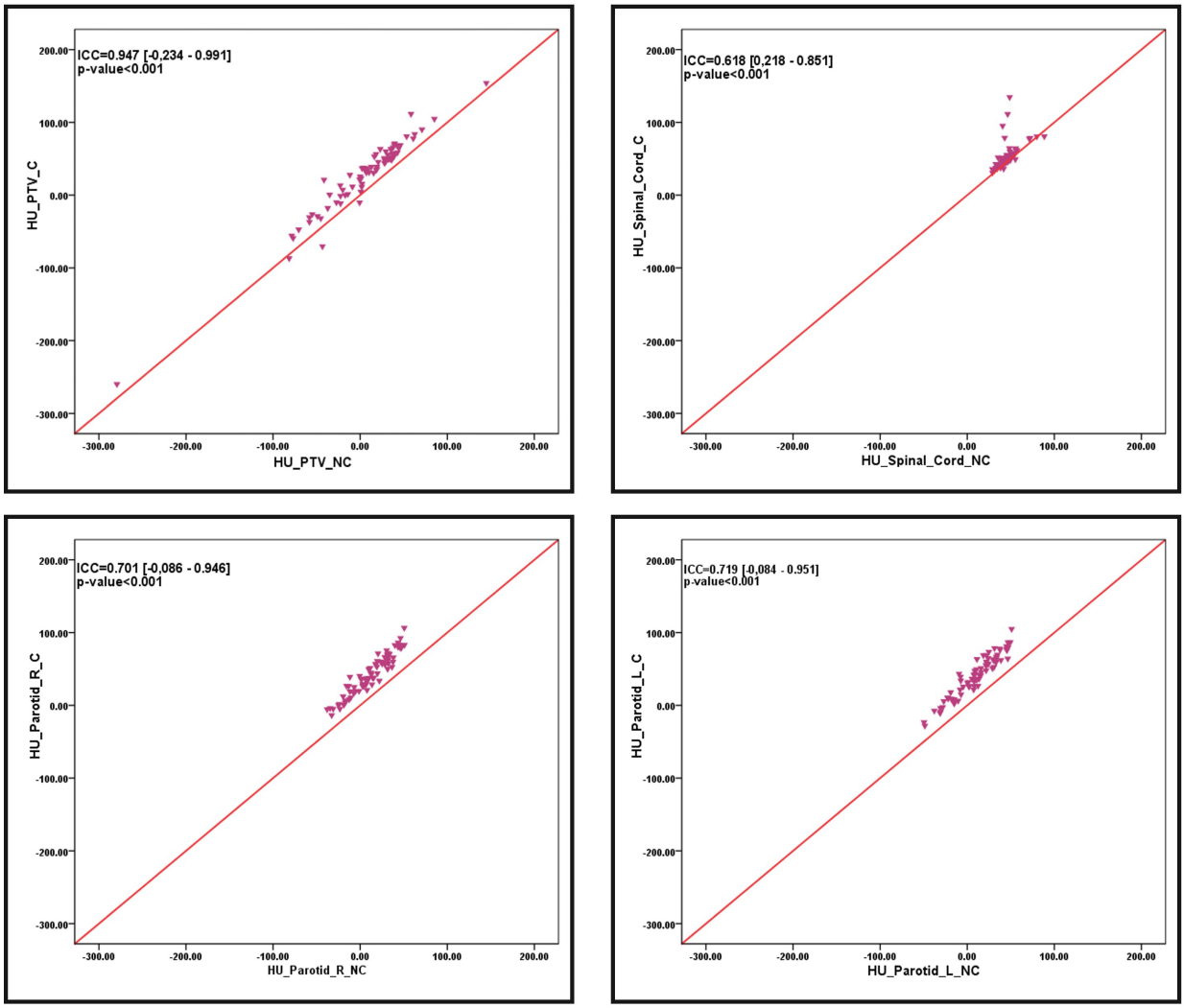
Supplementary



Supplementary Figure 1. HU mean comparison for PTV and OARs volumes in contrast and non-contrast CT.