The feasibility study of dual-energy CT virtual non-contrast instead of true non-contrast in proton radiotherapy dose calculation

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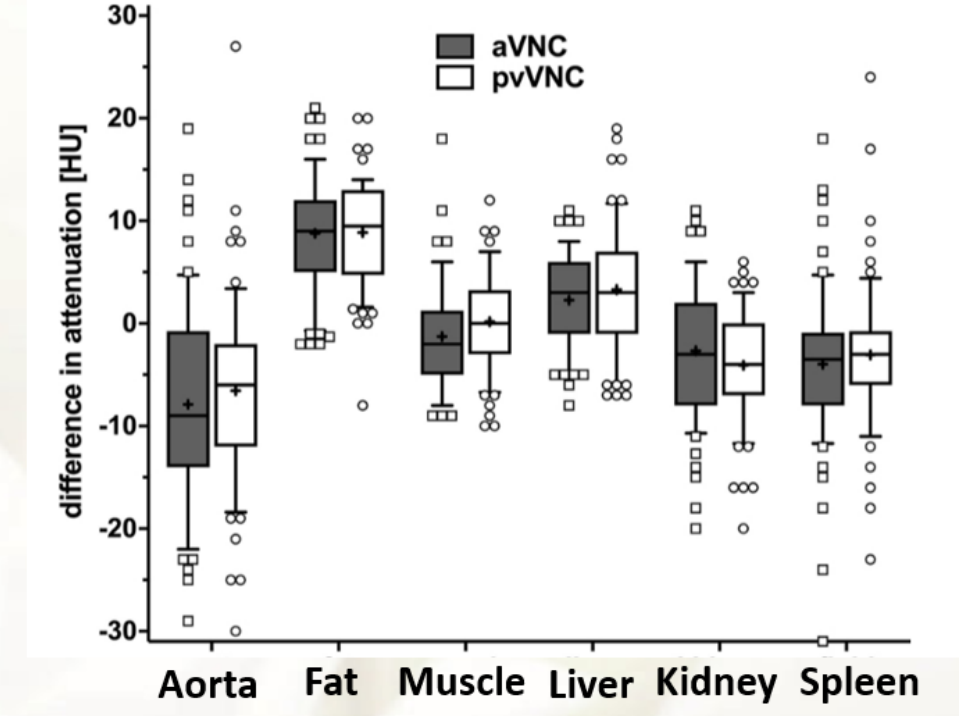
Background

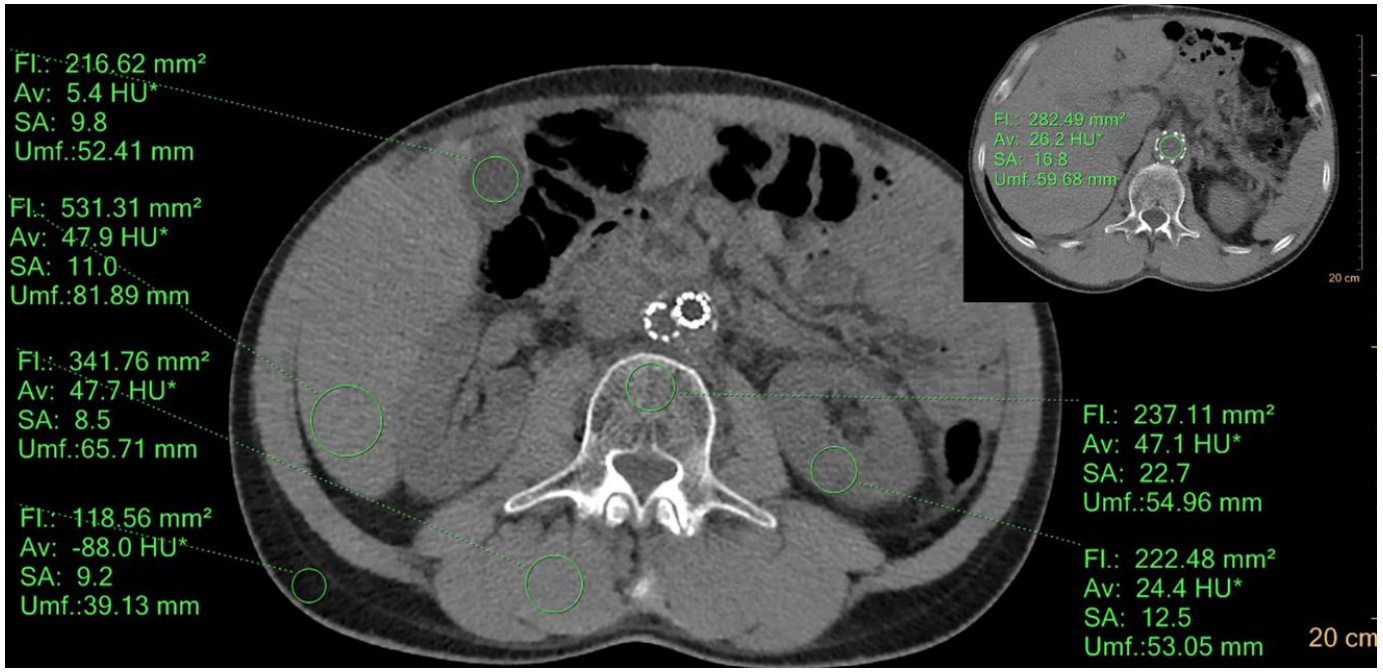
- In the conventional radiotherapy process, enhanced CT is used for outlining the visible tumor target area and lymph node prevention area, while non-contrast CT images are used for formulating radiotherapy plans.
- Dual-energy CT only needs to perform one enhanced scan. The generated virtual non-contrast (VNC) images can replace true non-contrast (TNC) images for formulating radiotherapy plans, which significantly reduces the radiation dose.

true non-contrast (TNC) Enhanced CT virtual non-contrast (VNC)

Background

literatures comparing the HU differences between VNC and TNC





Andreas P. Sauter, et al. European Journal of Radiology, 2020

The differences in HU among different organs and anatomical structures
In most cases, the deviation < ±20 HU

Previous studies have conducted analyses using organs or tissues as the unit.
What would the situation be if we examine the images layer by layer?

Purpose

1. Compare VNC and TNC images layer by layer and perform a comprehensive analysis.
2. Assess the correlation between VNC and TNC in regions showing large differences in HU.
3. Study on the feasibility of using VNC instead of TNC for photon and proton radiotherapy dose calculation in the cranial region.

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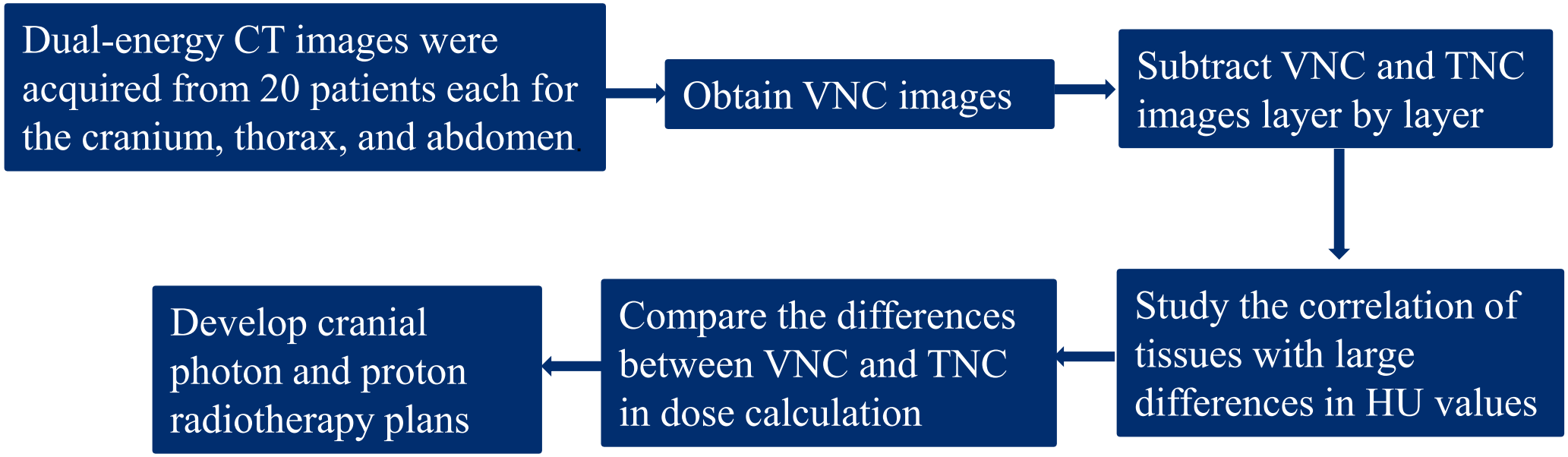
Image Acquisition 、 Image Post-Processing and Data Analysis



Introduction to Home-Made Software

1. This Home-Made software was developed in C++ and Qt.
2. After importing any two sets of DICOM images of a patient, a difference image based on layer-by-layer subtraction of HU values can be obtained.

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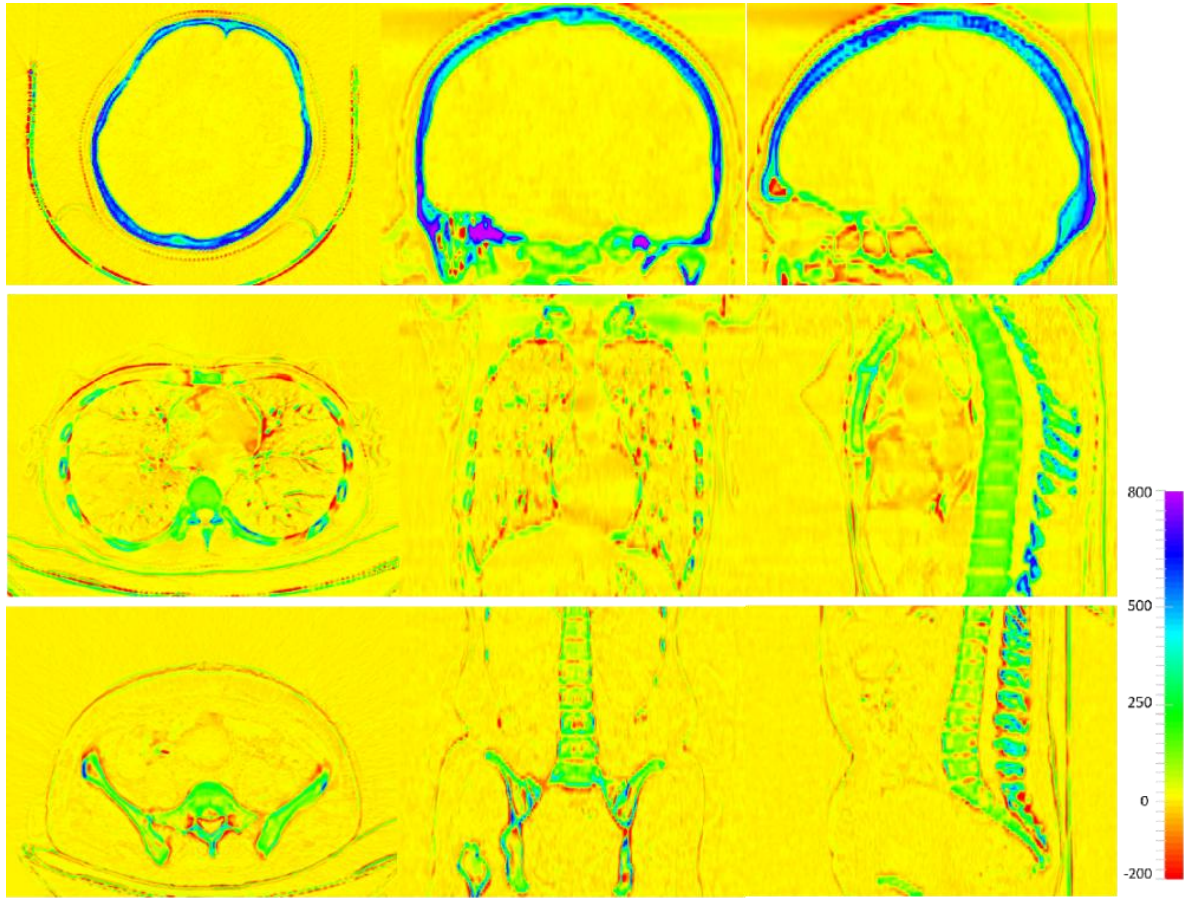
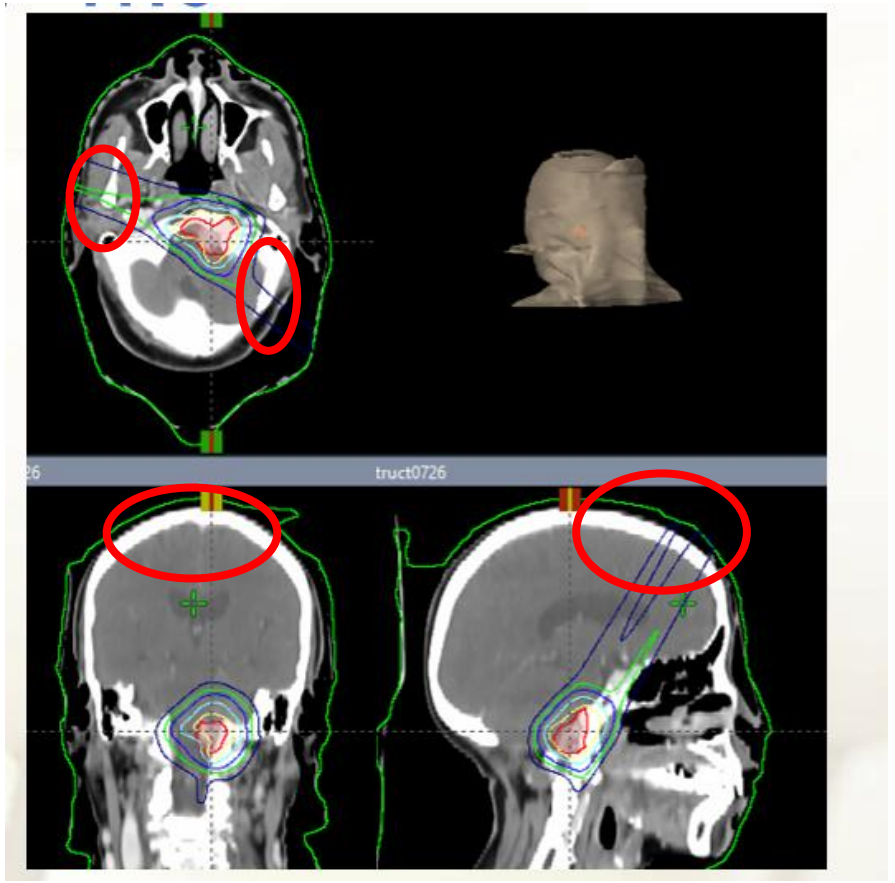
Result 1:Visualize the difference in HU values between VNC and TNC

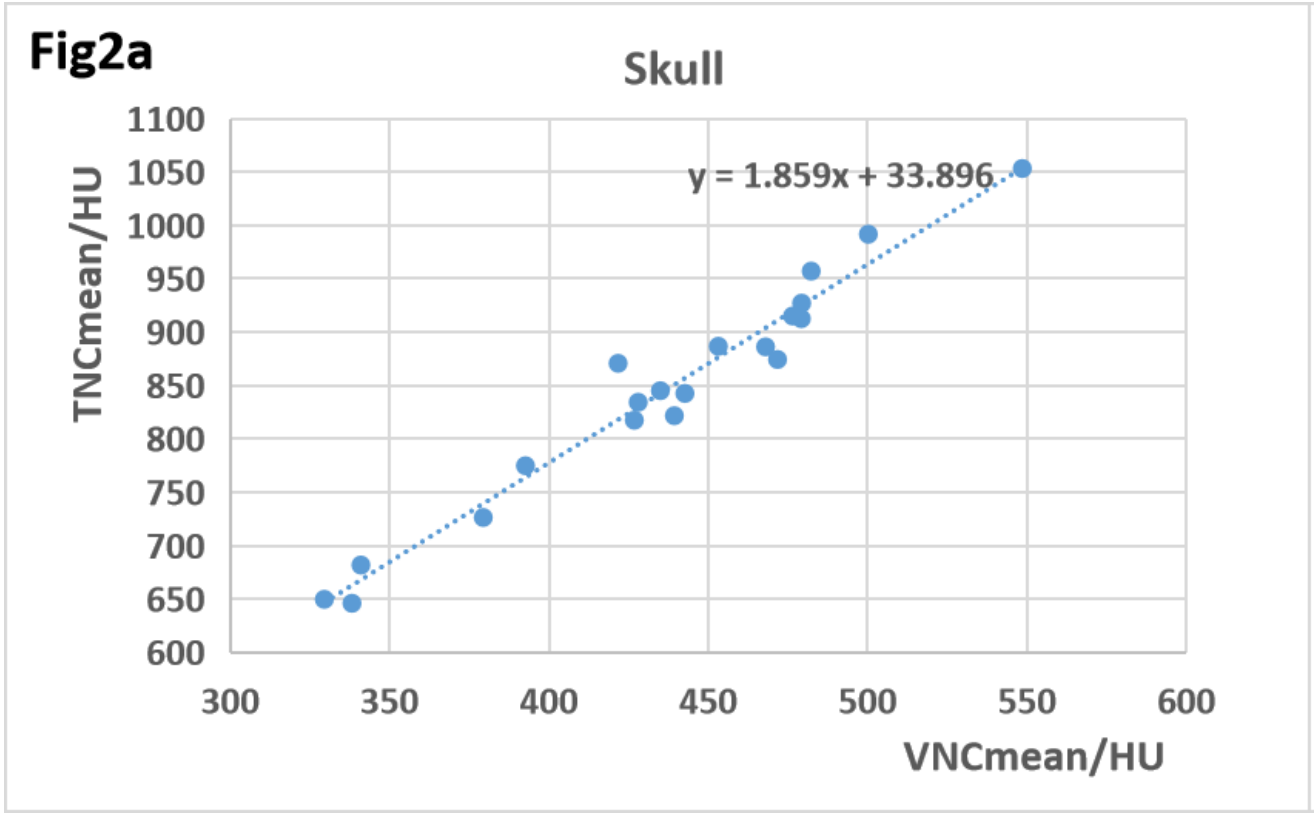


- The differences in bone structures were the most significant.



- In such proton radiotherapy plans, the bone structures around the target volume are abundant.
- Can virtual non-contrast (VNC) images be used for dose calculation?

Result 2:Correlation analysis results of skull HU values.



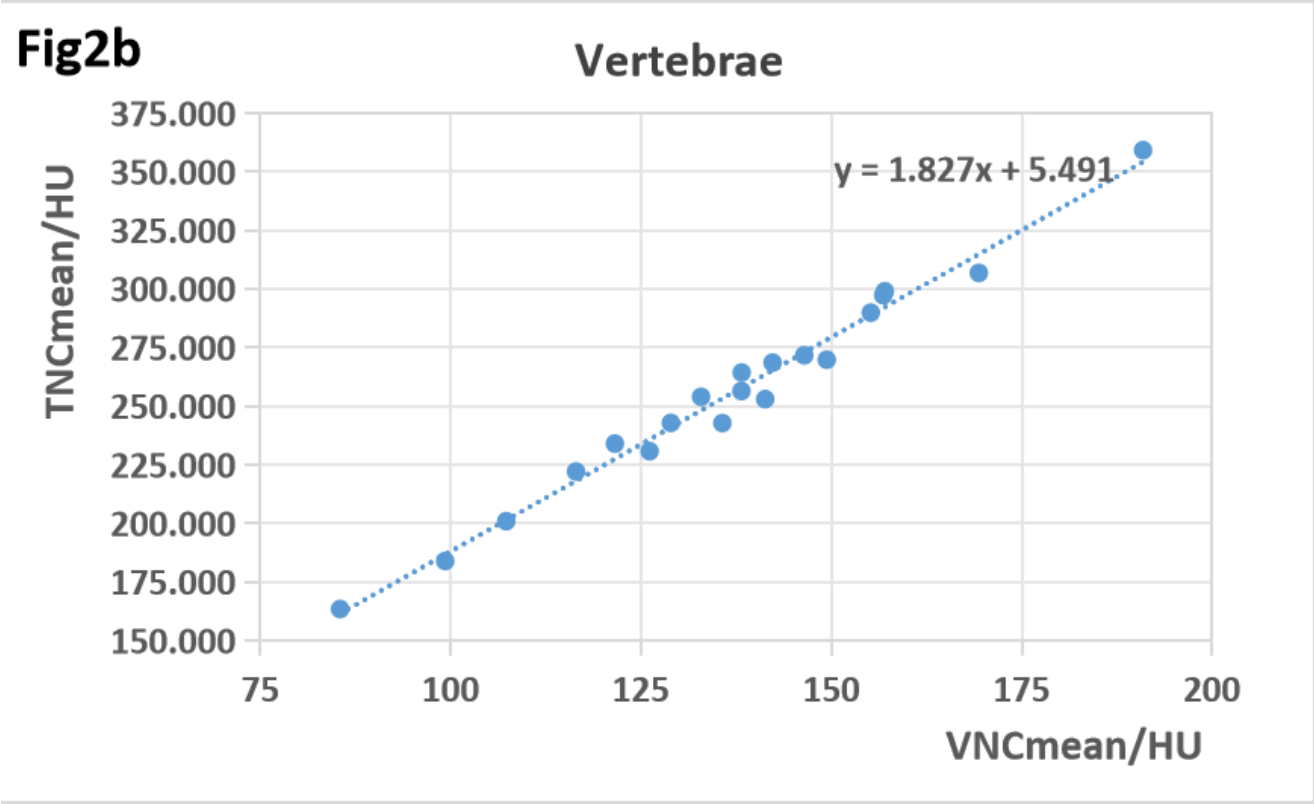
r=0.981

Skull TNC=1.859VNC+33.896

VNCmean	TNCmean	VNCmean	TNCmean
421.671	870.736	479.146	912.552
434.931	845.081	479.251	927.078
482.247	957.102	467.934	886.155
439.319	821.636	427.980	834.264
426.767	817.400	338.887	652.870
329.511	649.642	453.115	886.647
471.682	874.320	476.414	915.074
442.631	842.539	500.167	991.656
548.474	1053.218	338.186	645.953
379.369	726.296	340.989	681.755

Skull HU Values of 20 Patients

Result 2:Correlation analysis results of vertebrae HU values.



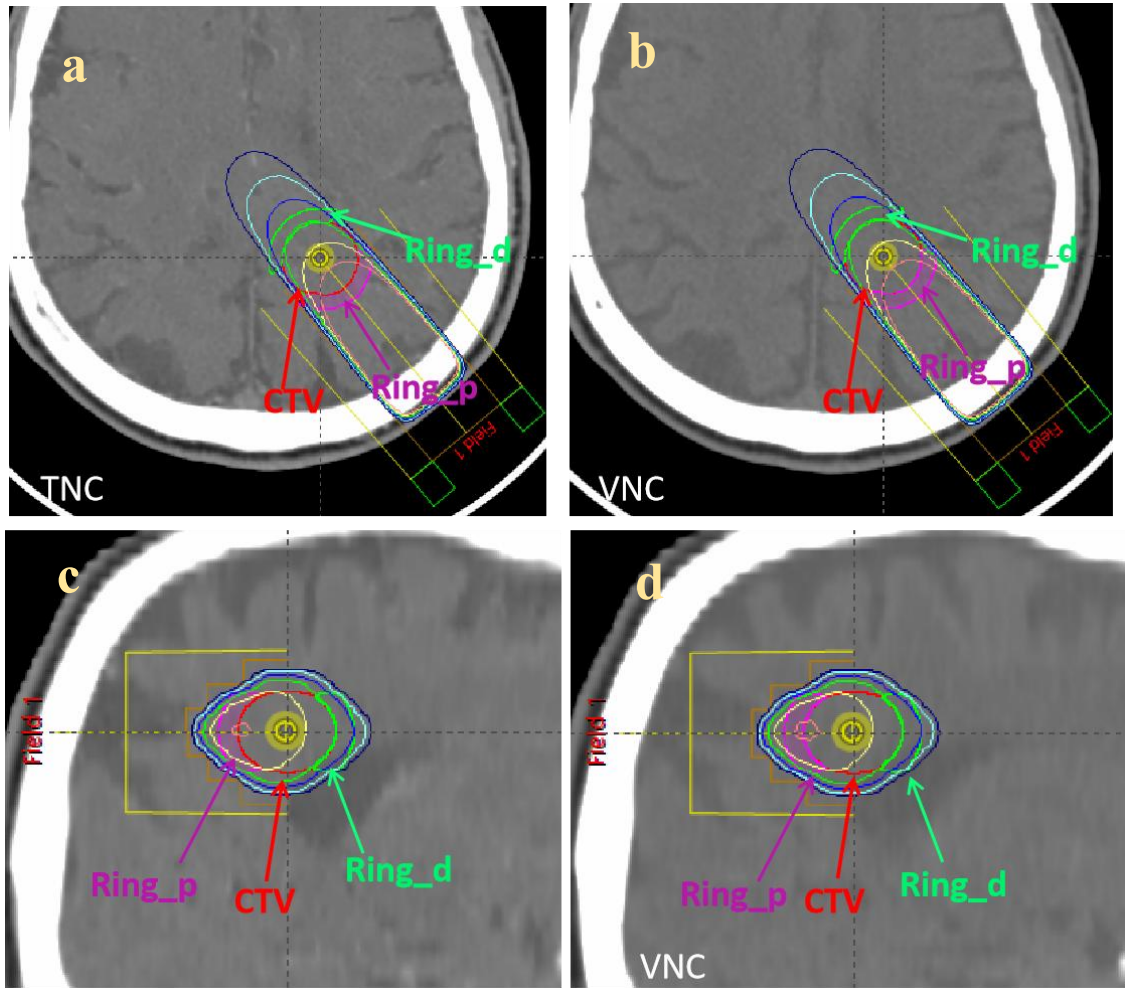
r=0.994

Vertebrae TNC=1.831VNC+5.18

VNCmean	TNCmen	VNCmean	TNCmean
155. 167	289. 910	128. 910	242. 914
126. 121	230. 822	157. 021	299. 029
138. 178	256. 493	132. 876	254. 040
146. 429	271. 736	116. 452	222. 179
190. 935	359. 217	141. 297	253. 036
107. 279	200. 979	142. 272	268. 606
135. 673	242. 832	149. 383	269. 848
99. 267	183. 999	121. 557	234. 070
169. 363	306. 870	138. 210	264. 386
156. 798	297. 365	85. 454	163. 504

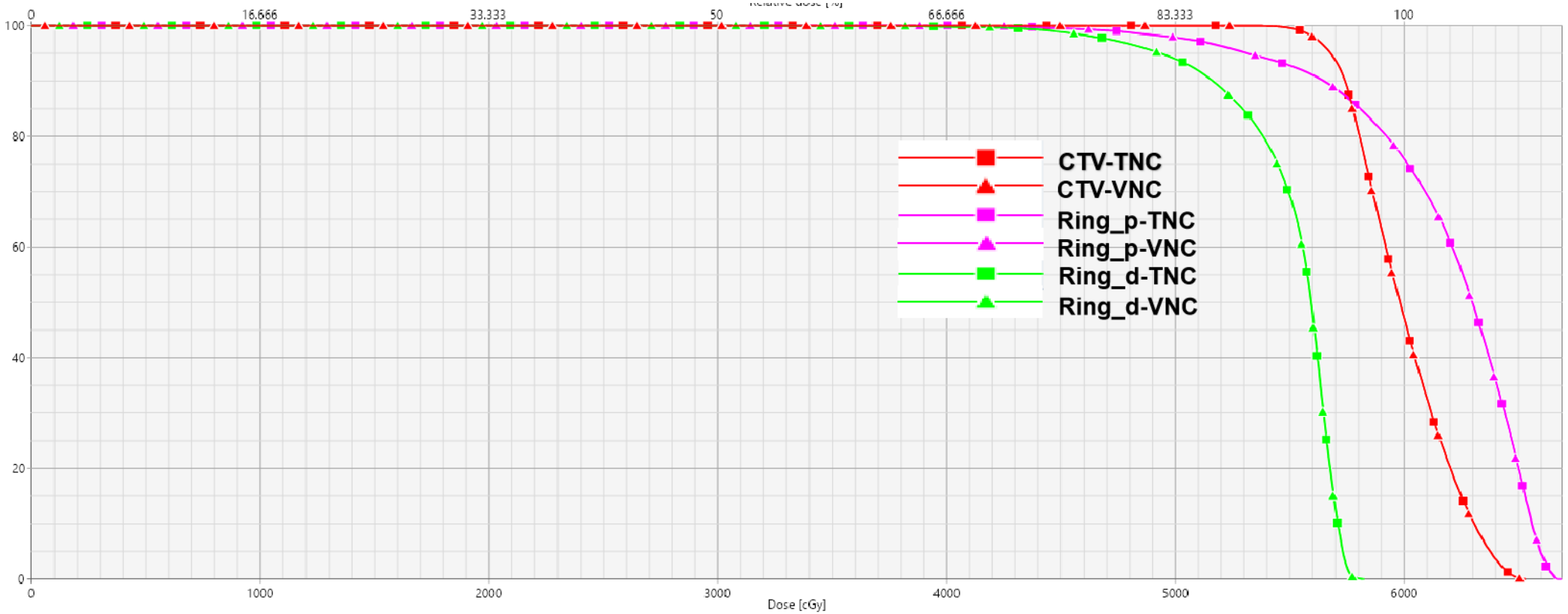
Vertebrae HU Values of 20 Patients

Result3 : Differences in photon radiotherapy dose calculation between VNC and TNC for cranial patients.



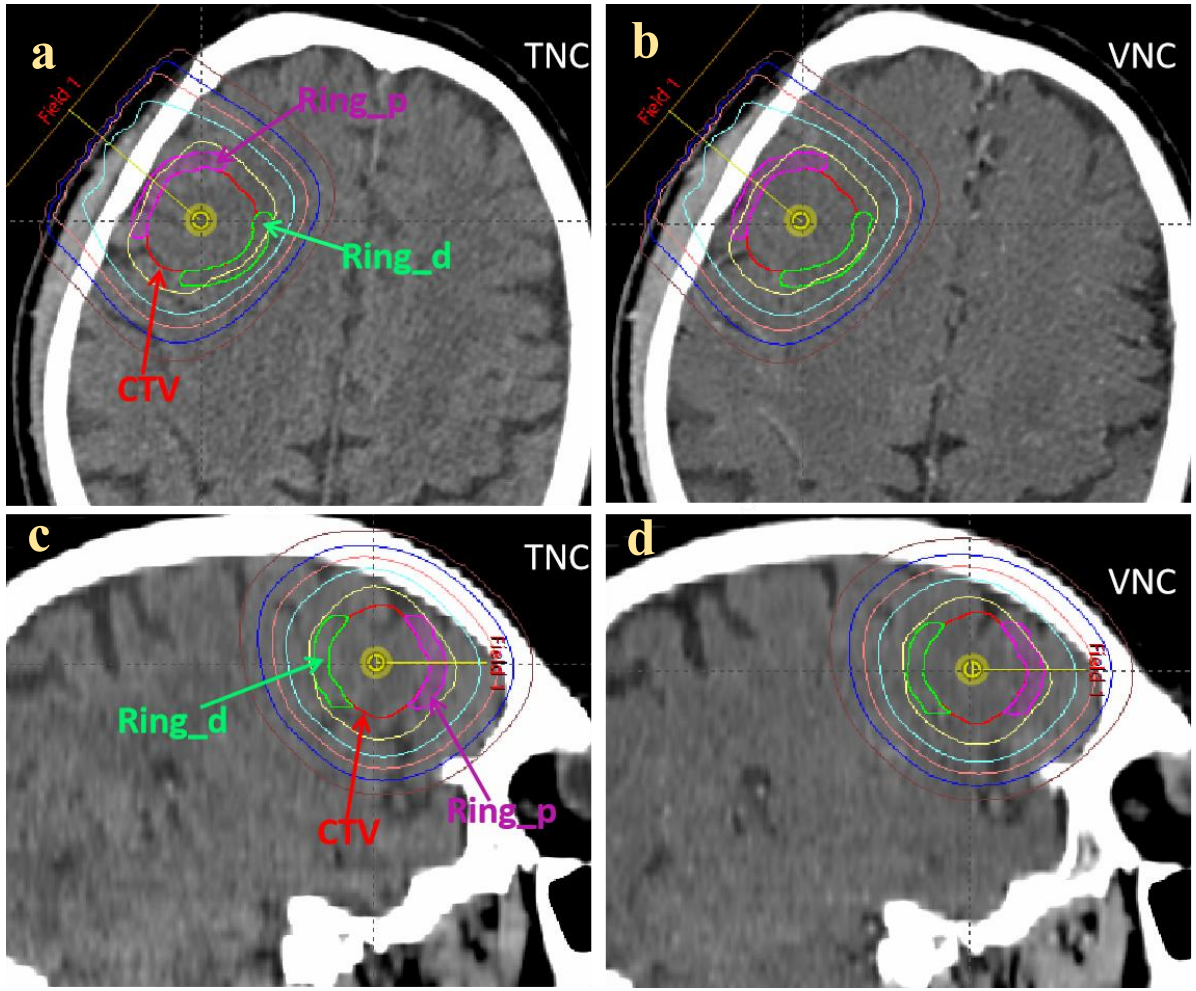
- The photon radiotherapy plans for TNC (a, c) and VNC (b, d) in a cranial patient.
- (a) and (b) are transverse slices; (c) and (d) are sagittal slices.
- The red area is the CTV, and the purple and green areas are the 0.4 cm anterior and posterior expansions of the CTV.
- The pink, yellow, light green, blue, cyan, and dark blue isodose lines correspond to 6300, 6000, 5700, 5400, 5100, and 4800 cGy, respectively

Differences in photon radiotherapy dose calculation between VNC and TNC for cranial patients.



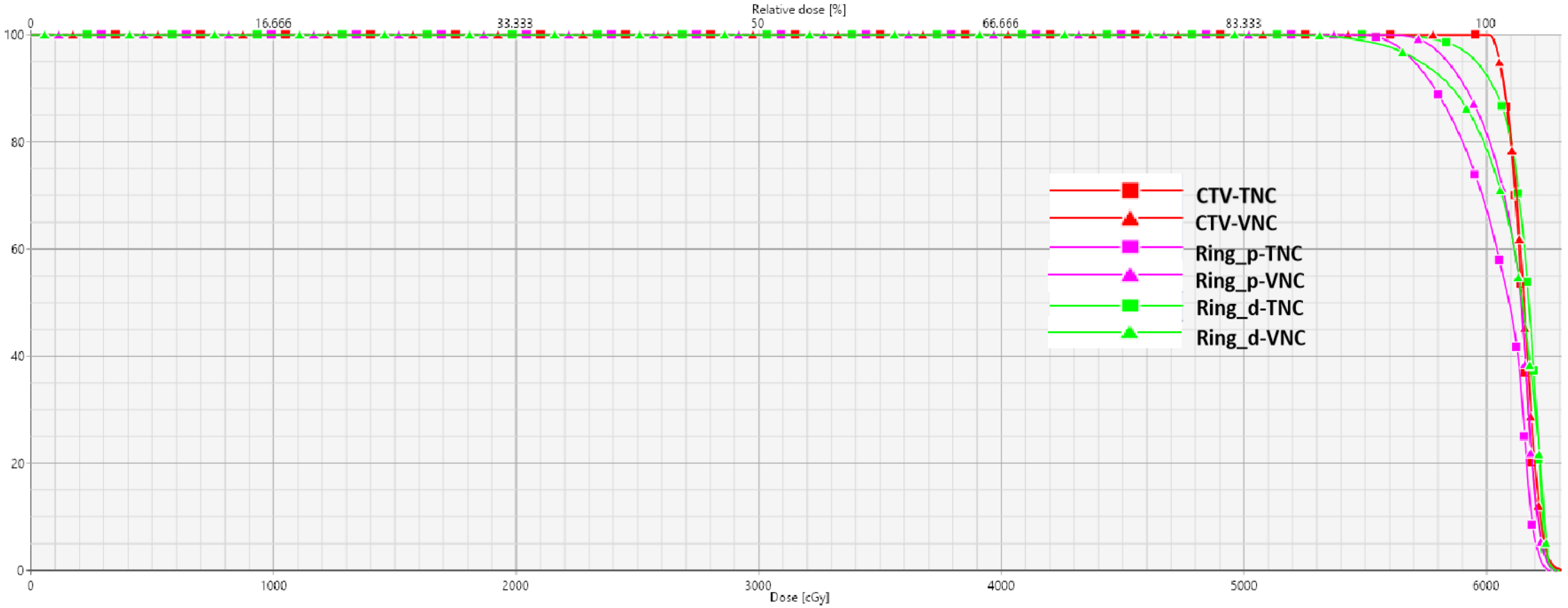
- Dose volume histogram calculated using the TNC and VNC photon radiotherapy plans.
- The DVH curves of the CTV, Ring-p, and Ring-d in the two photon radiotherapy plans almost overlap and are indistinguishable.

Result 3: Differences in proton radiotherapy dose calculation between VNC and TNC for cranial patients.



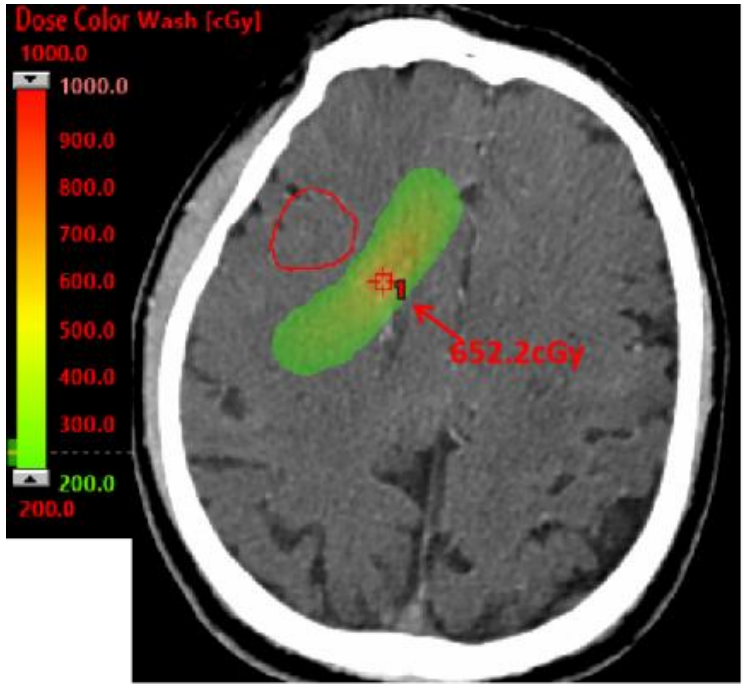
- The proton radiotherapy plans for TNC (a, c) and VNC (b, d) in a cranial patient.
- The yellow, cyan, pink, blue and brown isodose lines are 5040, 4356,4032, 3276, 2520, and 1008 cGy, respectively.

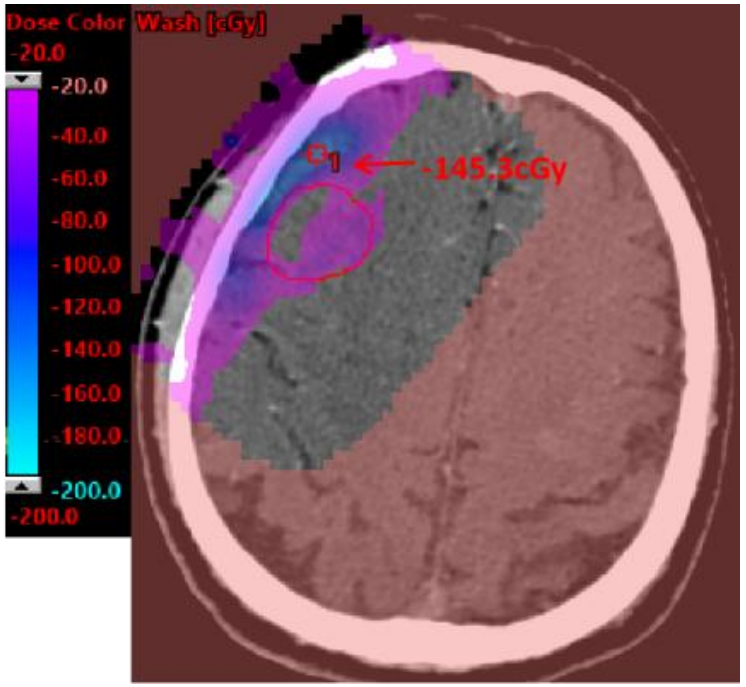
Differences in proton radiotherapy dose calculation between VNC and TNC for cranial patients.



- Dose volume histogram calculated using the TNC and VNC photon radiotherapy plans.
- The DVH curves of the CTV in the two proton radiotherapy plans almost overlap, while there are certain differences in the Ring-p and Ring-d regions.

Difference in dose distribution of the TNC and VNC proton radiotherapy plans





Behind the CTV, the maximum dose difference can reach 652.2cGy;

and in front of the CTV, the maximum dose difference can reach -145.3cGy.

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Conclusion:

- **The differences between VNC and TNC are mainly concentrated in the areas containing bones, the skull and vertebrae are the most prominent.**
- **There is a strong connection between the HU values of the VNC and TNC in skull and vertebrae, and the TNC HU values can be predicted based on VNC HU values in these areas.**
- **For cranial patients, VNC is not appropriate to replace TNC for proton radiotherapy dose calculation.**

THANKS

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