Abstract

"Optimization of the computed tomography protocol used for patients with advanced-stage lung cancer undergoing follow-up"

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Purpose:

The aim of this work is the optimization of the computed tomography protocol used for patients with advanced-stage lung cancer undergoing follow-up. The acquisition of two new Philips Ingenuity CT devices equipped with an iterative image reconstruction algorithm (iDose4), replacing the previously supplied Philips Brilliance devices, provided the opportunity for this analysis.

Materials and methods:

In an initial phase, *phase zero*, the effects of the introduction of an iterative reconstruction algorithm on the dosimetric indices of computed tomography (CTDIvol and DLP) and on the noise of diagnostic images in the transition from old to new equipment were analyzed. Eleven patients were identified who had undergone at least one examination with both the previous and current equipment. A noise analysis was performed for each pair of images acquired previously on Brilliance and later on Ingenuity. At the same time the percentage difference in the value of CDTI was calculated. Then, using the acquisition parameters recorded by the Dose Watch dose-tracking software, an organ dose analysis was performed with the CT-Expo calculation software.

Subsequently, in *phase one*, measurements were performed using a Catphan600 technical phantom with the aim of characterizing the response of the system in terms of optimization in relation to the variations of the typical parameters of Philips tomographs: DoseRight Index for dose reduction and iDose4 for iterative image reconstruction processes. The variation of the CTDIvol and noise as a function of the DRI was calculated. The DRI was varied from 25 to 3, in order to contain an upper margin and a lower margin compared to the reference value currently used (DRI = 18). For each acquisition, on the homogeneous module of Catphan (CTP486) the noise intended as standard deviation of an ROI of area 1125 mm^2 was calculated and the value of the CTDIvol recorded. Subsequently, measurements were performed to verify the decrease in the ability to resolve low contrast (CNR) as the DRI decreases and to investigate the trend of the CNR as a function of the iDose4 level. Module for low contrast analysis (CTP515) was used; the CNR analysis was performed by positioning two ROI of area 120 mm^2 as shown in *fig.1*, in which the ROI1 is positioned on the low contrast insert and the ROI2 is positioned in the center for the measurement of the bottom. The following formula was used to calculate the Contrast to Noise Ratio:

$$CNR = \frac{M_1(contrast\ pin) - M_2(background)}{[\sigma_1(contrast\ pin) - \sigma_2(background)]^{\frac{1}{2}}}$$

Then, the noise spectrum was analyzed as a function of the reconstruction filters (standard, smooth and sharp) and the set iDose4 level (3, 4 and 5).

In *phase two*, the use of the anthropomorphic PIXY phantom was used to carry out some measurements in a condition that was as likely as possible to the real one, in which the examination is performed on the patient. The objectives of the measures were to verify the reduction of the dose resulting from the reduction of the DRI and to verify the ability to recover the low contrast resolution following a unit increase of iDose4.

Finally, in *phase three*, the dose indices relative to the two acquisition protocols, chest-abdomen (CTDIvol = 12 ± 5 and DLP = 820 ± 408) and skull (CTDIvol = 48 ± 10 and DLP = 1017 ± 208) were compared with the Diagnostic Reference Levels indicated by the Istituto Superiore di Sanità (ISTISAN 17/33.

Result:

Phase zero: noise assessment on patient images acquired previously on Brilliance and later on Ingenuity resulted in an average decrease of 31.3% for thorax-abdomen images and 7.1% for skull images. At the same time, a reduction of the CTDIvol of 25% and 16.4% respectively was observed. The organ dose analysis showed an average dose reduction in the brain of 16.3%, in the lung by 25% and in the heart by 24.9%.

Phase one: the variation of the CTDIvol and of the noise as a function of the DRI was calculated, obtaining on average that, to each unit increase of the DoseRight Index corresponds a decrease in noise equal to 5.4% for CT Ingenuity 64 and 5.9% for CT Ingenuity 128, and vice versa. At the same time, the same variation of the DoseRight Index corresponds to an increase in the CTDIvol equal to 11% for CT Ingenuity 64 and equal to 11.9% for CT Ingenuity 128, and vice versa. These results are in accordance with the values declared by the manufacturer. The analysis of the nNPS showed unexpected differences: for the Ingenuity 64 the noise spectrum (nNPS) is approximately constant as the iterative level varies (from iDose4 = 3 to iDose4 = 4); for the Ingenuity 128 tomograph, the same increase clearly changes the trend of the nNPS. On the contrary, a further increase from iDose4 = 4 to iDose4 = 5 modifies the noise spectrum in Ingenuity 64, while this does not happen in Ingenuity 128.

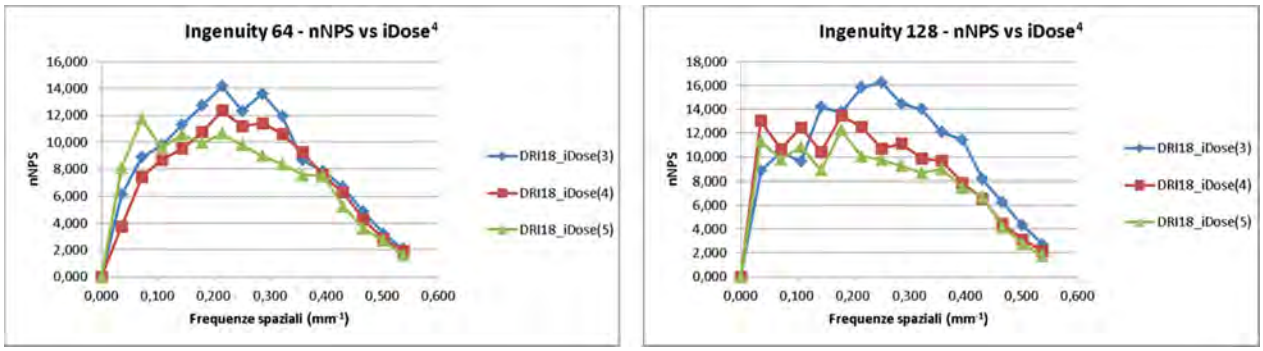

Figura 1: nNPS as funcion of three levels of iDose4, for Ingenuity 64 and Ingenuity 128

Phase two:it was found that the reduction of the DoseRight Index from 18 to 16 produces a decrease of the CTDIvol equal to 20.3%, and that the contrast is completely recovered when passing from iDose4 = 3 to iDose4 = 4. It was therefore considered possible to optimize the protocol with the following parameters: DRI = 16, iDose4 = 4.

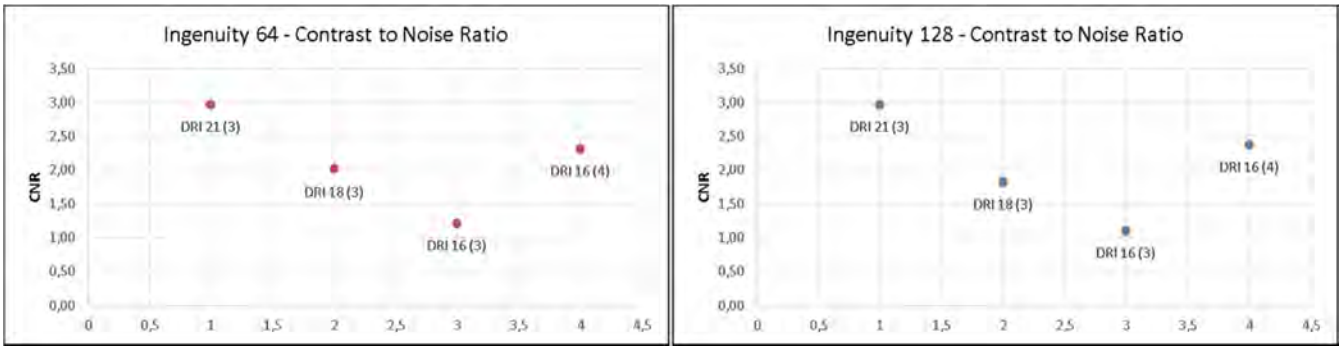

Figura 2: values as a function of acquisition and reconstruction parameters, for Ingenuity 64 and Ingenuity 128

By applying these new parameters to the Philips Ingenuity, a reduction in the total dose in terms of CTDIvol has been obtained which exceeds the typical values of Philips Brilliance by 40%.

Phase three: both dose indices relative to the two acquisition protocols, chest-abdomen (CTDIvol = 12 ± 5 and DLP = 820 ± 408) and skull (CTDIvol = 48 ± 10 and DLP = 1017 ± 208) are, on average, within the values considered. However, some CTDIvol values higher than those indicated by the ISS were recorded, for which a reason was sought. As regards the skull acquisition protocol, the higher values of the CTDIvol, in some cases, is attributable to an imprecise application of the protocol by the technical staff who carried out the examination. In the case of the thorax-abdomen protocol, however, the most likely cause of the rise in some values of the CTDIvol was assumed to be the size and weight of the patient as shown by the BMI values.

Conclusion:

This study made it possible to optimize the dose of the thorax-abdomen acquisition protocol and to identify typical values for the dosimetric indices to be used as a reference for the future optimization of CT acquisition protocols.

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