Analysis of the Efficiency of Iterative Reconstruction Techniques in Reducing Radiation Dose in Computed Tomography: A Clinical Feasibility Study

ABSTRACT

Aims: This study aimed to evaluate the influence of different interactive reconstruction (IR) techniques between computed tomography (CT) equipment to reduce radiation dose during clinical practice, since CT is considered a valuable medical imaging technique and is widely used in clinical practice.

Study design: clinical feasibility study.

Place and Duration of Study: The study was carried out over a semester at a reference clinic in imaging diagnostics located in Rio Grande do Sul, Brazil.

Methodology: Methodology: This study describes the efficiency of iterative reconstruction in the three most common examinations in clinical practice, namely: skull, chest and abdomen. Using two 64-detector row CT scanners, one with and one without IR, and to support data interpretation, a literature review on CT equipment, dosage and protocols was performed.

Results: Iterative Reconstruction tends not to result in a significant reduction in radiation dose in all types of examinations. The method varies according to the region of the body, being more significant in the thorax and abdomen and less significant in the skull. However, the application of IR has a smaller standard deviation compared to the conventional technique.

Conclusion: The most favorable results were achieved by the CT scanner that did not use Iterative Reconstruction. Since the equipment with the application of IR recorded higher radiation exposure rates compared to the CT scanner without this functionality. It is worth noting that the lower the radiation dose and the higher the quality of the radiographic image, the greater the patient's safety during the procedure.

Keywords: *Tomography Computed; Dose; Iterative Reconstruction; Image Processing; Clinical Protocols.*

1. INTRODUCTION

Computed tomography is considered a valuable medical imaging technique and is widely used in clinical practice. Compared to a simple radiograph, CT typically requires higher doses due to the need for greater anatomical detail. Therefore, the procedure can subject the patient to a high dose of radiation [9]. In Brazil, the National Health Surveillance Agency (ANVISA) has strict criteria regarding the use of radiation, including the Collegiate Board Resolution (RDC) No. 611 regarding the guarantee of quality examinations and radiological protection in Computed Tomography, since it is an operational necessity [1].

In addition, the ALARA principle, which stands for 'as low as reasonably achievable', guides radiology professionals to maintain clinical image quality by exposing the patient to the lowest possible dose of radiation [11]. One of the possible solutions for dose reduction is the use of Iterative Reconstruction techniques, instead of Traditional Reconstructions (RT) [2].

The use of tools that emphasize diagnostic investigation, such as multiplanar reconstructions, three-dimensional rendering and artifact reduction techniques, can further improve the diagnostic capacity of CT [6]. New associated technologies for CT image reconstructions are essential for the image noise reduction capabilities, and IR may have the potential to significantly reduce the dose in patients undergoing CT without compromising image quality [10].

To assess the radiation dose that a patient receives during a tomographic examination, three types of Dose Index (CTDI) are used. These are parameters that quantify the radiation doses that a patient receives during a CT examination. It is responsible for assessing the dose and ensuring patient safety, calculating the dose distribution to which the patient is being exposed based on the average absorbed dose at different angles of sections of the patient's body, represented in the unit of milligrays (mGy), always considering the intensity of the radiation and the thickness of the sections. Typically, these CTDI results are used by radiology professionals to optimize examination protocols, ensuring an adequate and safe radiation dose to patients [5].

Thus, the evolution of computed tomography over the different generations has brought significant improvements in image quality and in the reduction of the radiation dose applied to patients. Since the first generations, in which the radiation dose was relatively high, technological advances have allowed faster acquisition, greater spatial resolution and lower exposure to X-rays, contributing to the safety and efficacy of this great radiodiagnostic resource [3]. Therefore, the present study evaluated the influence of different interactive reconstruction techniques between CT equipment to reduce radiation dose during clinical practice.

2. MATERIAL AND METHODS

This study evaluated the effectiveness of Iterative Reconstruction in reducing radiation dose in computed tomography scans. Images from two 64-detector row CT scanners, one with and one without IR, were compared in skull, chest, and abdomen scans. The research involved three steps: selection of anatomical structures, selection of images for comparison, and dose analysis. However, to support data interpretation, a literature review on CT equipment, dosage, and protocols was performed. Therefore, below it is possible to observe some concepts that were defined with the objective of creating a table for quality analysis related to radiation dose in CT.

The first concept established was pitch, which can be defined as the relationship between the distance traveled by the examination table and the thickness of the radiation beam. It directly affects the speed of image acquisition and the radiation dose that the patient receives. The higher the pitch, the higher the speed of the table's advancement and the lower the overlap between the acquired images. In contrast, acquisitions with higher speed have less anatomical detail. On the other hand, decreasing the pitch to reduce the advancement speed and obtain more detailed images increases the patient's exposure to radiation [13].

The definition of noise and the study of the signal-to-noise ratio (SNR) were necessary for the present work. Since this parameter is represented by the standard deviation of the measured CT numbers, some of the factors responsible for the noise level of an image are slice thickness, tube voltage and current, size of the scanned object, and reconstruction algorithms [7]. SNR is the combination of the effects of contrast, resolution, and image noise. The higher the signal and the lower the noise, the better the image quality. Images with high SNR allow the recognition of smaller, lower-contrast structures, and human detection capacity improves with higher SNR [12]. Regarding the CT number, it is considered that areas with lower radiation absorption appear darker in the images and those with higher absorption result in lighter images, according to the tomography unit scale, called the Hounsfield scale (HU) or CT Number [3]. This scale varies between -1000 (air) and +1000 (bone), covering all levels of absorption in the human body, from the softest tissues to the bones [4].

Research related to CT image reconstruction by filtered backprojection clarified that the data acquired by the detectors during the scanner scan are back projected to each pixel of the image and filtered to reduce noise artifacts and increase sharpness. In this process, the projections are filtered before being added to form the resulting image, but this does not guarantee good image quality, especially in cases where there is high attenuation. On the other hand, filtered backprojection occurs through repeated interactions, where the images are progressively refined through advanced calculations and algorithms. In other words, the image gradually obtains greater quality with improved contrast and increased sharpness [10].

The interactive reconstruction algorithm can reduce image noise, with level 1 being the least aggressive reduction, and level 7 being the most aggressive [8]. It should be taken into account that the higher the level used.The greater the artificial appearance in the images, that is, the professional responsible for acquiring the images must always be attentive and evaluate which level is most appropriate to use in order to achieve the objective of improving image quality [2]. Based on this research, the following table was created (table 1).

Table 1. Methodology used to obtain the quality vs radiation dose analysis in CT.

Request	Med. (A x L cm²)	Slice Thickness (mm)	No. of CTs	Noise (SD)	Mod. Dose	Pitch	Max mA.s	IR	CTDIV (mGy)

After creating the table, for comparison purposes, the images were acquired on a 64-detector row CT scanner, in axial sections, considering: height, width and thickness of the sections. All criteria were standardized according to each area analyzed; the parameters are based on generating an index that considers height vs. width (H x W).

In the case of the skull, the index was fixed at approximately 361 cm², given the smaller and more uniform dimensions of this region. Figure 1 provides a visual representation of the methodology applied to skull images, showcasing the criteria used to analyze the dimensions and the steps taken to ensure consistency across the selected exams.

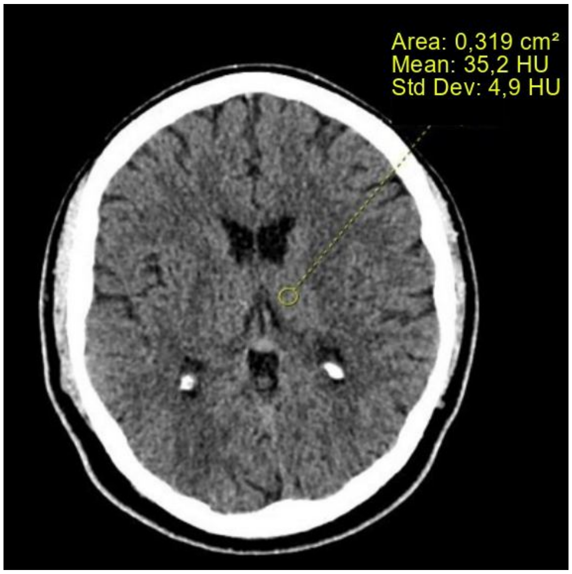

Fig. 1. Axial section of the skull at the level of the left thalamus. Area: 0.319 cm². Mean (number of CT scans): 35.2 HU. Std Dev (Standard Deviation/Noise): 4.9 HU.

In the thorax region, the images were analyzed using an index ranged from 700 to 800 cm². Figure 2 illustrates the process used to evaluate thoracic images, detailing how the dimensions were measured and highlighting the specific criteria used to maintain uniformity across the dataset.

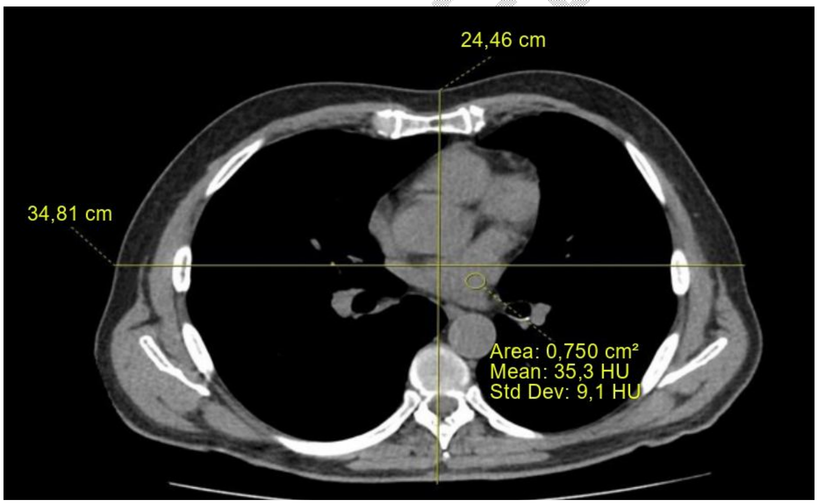

Fig. 2. Axial section of the thorax at the level of the left atrium. Height: 24.46 cm. Width: 34.81 cm. Area: 0.750 cm². Mean (number of CT scans): 35.3 HU. Std Dev (Standard Deviation/Noise): 9.1 HU.

For the abdomen, the index varied from 650 to 800 cm², reflecting the anatomical differences and the need for a broader range of parameters in this region. Figure 3 demonstrates the analysis of abdominal images, including the steps taken to measure and compare the height, width, and slice thickness of the sections, ensuring that the results were both accurate and reproducible.

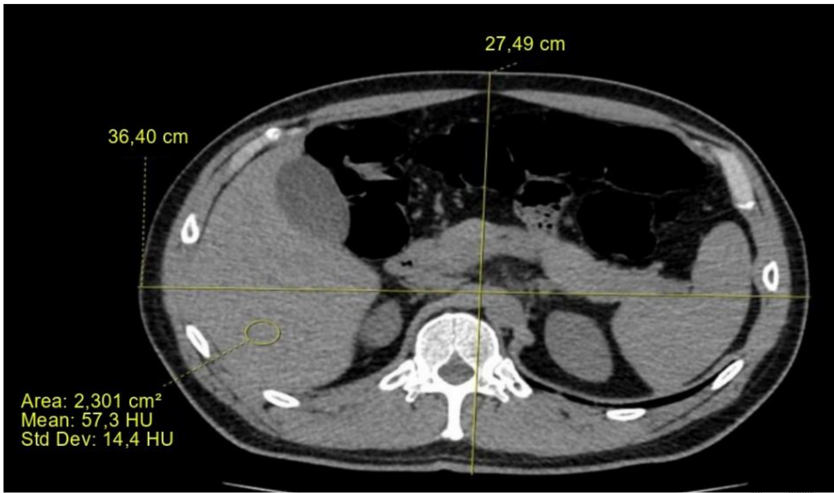

Fig. 3. Axial section of the abdomen at the level of the upper renal poles. Height: 27.49 cm. Width: 36.40 cm. Area: 2.301 cm². Mean (number of CT scans): 57.3 HU. Std Dev (Standard Deviation/Noise): 14.4 HU.

3. RESULTS AND DISCUSSION

The radiation dose from CT scans (CTDIV) per slice in the cranial region for scanners equipped with Iterative Reconstruction reveals an average CTDIV of 49.39 mGy, with a standard deviation of 0.11%. These values demonstrate consistent performance across the analyzed cases, reflecting the uniformity of the radiation dose delivered when IR is applied. In contrast, the CTDIV per slice for scanners without IR presents an average of 53.72 mGy, with a higher standard deviation of 2.79%. This variability indicates greater inconsistency in the dose delivered compared to scanners utilizing IR.

While the scanner equipped with IR achieved a slight improvement in reducing radiation exposure, the difference in the average doses (approximately 4.33 mGy) is minimal and does not align with the significant dose reduction of 20% to 80% claimed by IR technology. Despite the improved consistency observed with IR, its impact on dose reduction remains negligible for the cranial region in this study. Figure 4 illustrates the comparison of results for the cranial region with and without Iterative Reconstruction. The graphical data underscores the limited impact of IR on radiation dose reduction, highlighting the similarity in average dose levels between the two scanner types.

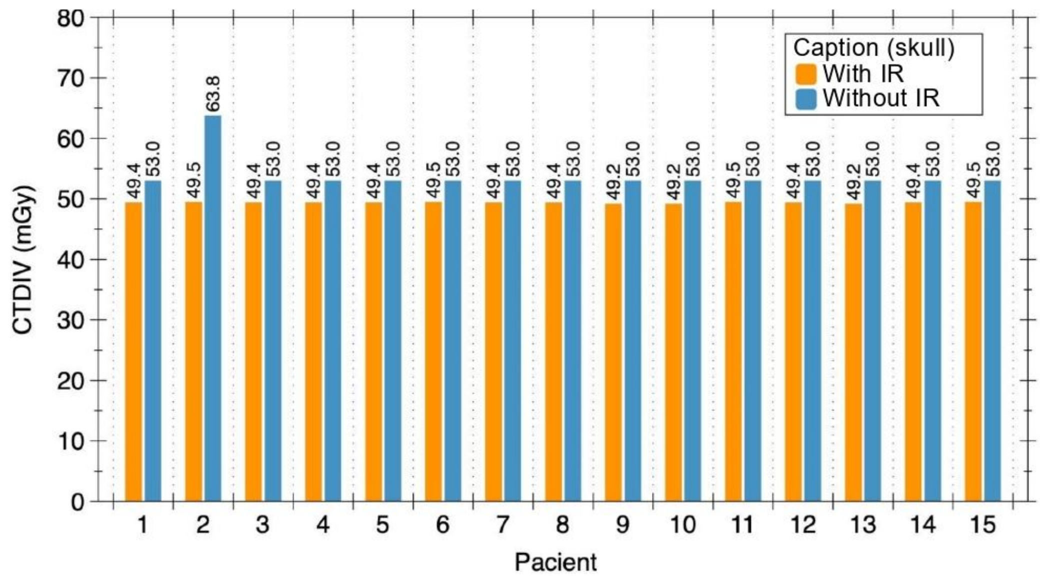

Fig. 4. Graphical representation comparing the results for the cranial region

The radiation dose from computed tomography per slice in the thoracic region for scanners equipped with IR showed an average CTDIV of 6.77 mGy, with a standard deviation of 0.59%. These values reflect consistency in the delivered dose when IR is applied. In contrast, for scanners without IR, the radiation dose showed an average CTDIV of 5.27 mGy, with a higher standard deviation of 1.25%. This variability suggests that, although less consistent, the scanner without IR achieves lower average dose values for the analyzed cases.

It is observed that the scanner equipped with IR does not fully meet the expectations described in the literature, as the average doses were 1.5% higher compared to the scanner without this technology. This indicates that, for the thoracic region, the use of IR did not result in a significant reduction in radiation exposure for patients. Instead, the scanner without IR demonstrated a lower radiation exposure rate, contradicting the premise that IR significantly reduces the radiation dose.

Figure 5 graphically illustrates the comparison of the results for the thoracic region with and without Iterative Reconstruction. The presented data demonstrates greater effectiveness in dose reduction for the scanner without IR.

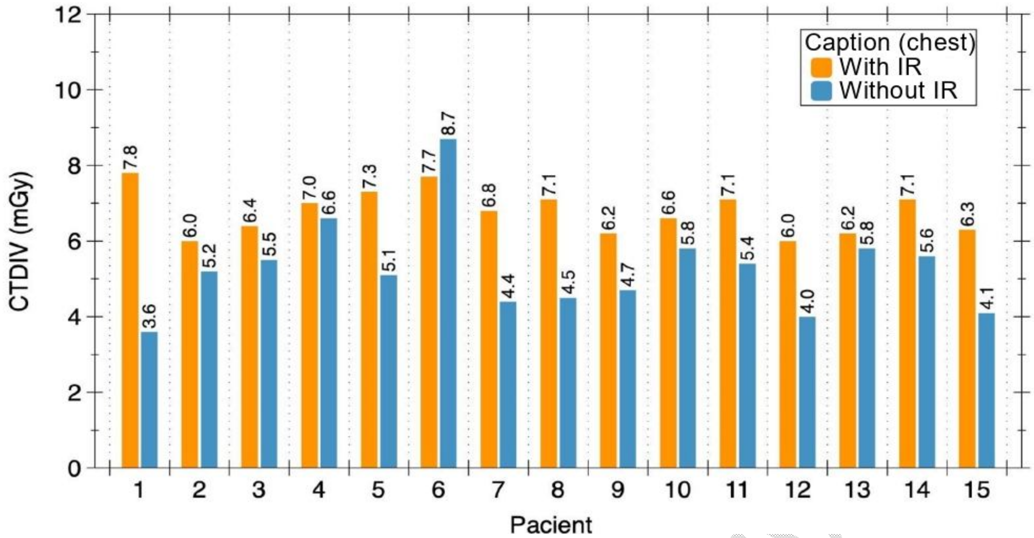

Fig. 5. Graphical representation comparing the results for the thoracic region

The analysis of the abdominal region revealed a significant difference in performance between the scanners. The scanner equipped with Iterative Reconstruction demonstrated a standard deviation of 0.87% and an average radiation dose of 16.11mGy. In contrast, the scanner without IR exhibited a slightly higher standard deviation of 0.97% but a substantially lower average radiation dose of 7.29mGy. This difference of 8.82% in favor of the scanner without IR raises concerns about the actual benefits of using IR technology in this context.

Figure 6 provides a detailed graphical representation of the comparison, further emphasizing the contrast between the scanners. It illustrates the higher dose variability and increases average radiation levels associated with the scanner using IR. These results underline the importance of critically assessing advanced technologies to ensure they meet their expected benefits in real-world applications.

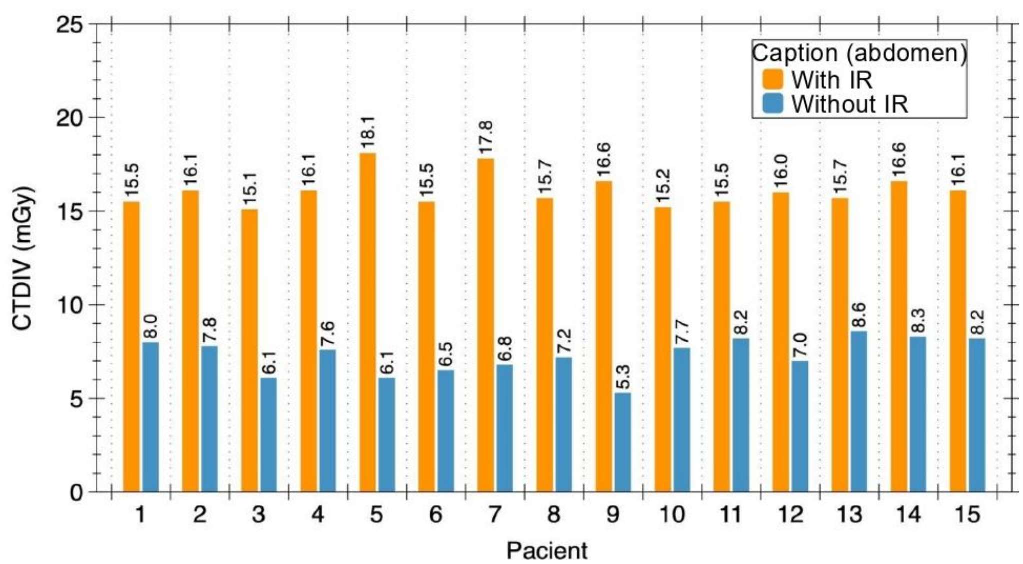

Fig. 6. Graphical representation comparing the results for the abdominal region

Table 2 presents a summary of the results obtained for the analyzed regions, both with and without Iterative Reconstruction.

Table 2. Mean and Standard Deviation of the studied examinations for both scanners with and without Iterative Reconstruction.

Region/Scanner	Mean	Standard Deviation
Cranial With IR	49.39mGy	0.11%
Cranial Without IR	53.72mGy	2.79%
Thoracic With IR	6.77mGy	0.59%
Thoracic Without IR	5.27mGy	1.25%
Abdominal With IR	16.11mGy	0.87%
Abdominal Without IR	7.29mGy	0.97%

Based on the results provided in Table 2, the mean values and standard deviations indicate a higher percentage of dose when IR is applied compared to the conventional technique without IR.

Overall, the results suggest that IR does not consistently result in significant radiation dose reduction across all types of examinations (Cranial, Thoracic, and Abdominal). While IR is widely cited in the literature for offering radiation dose reductions between 20% and 80%, this study indicates that such reductions may not always be achieved. The impact varies depending on the body region, being more pronounced in the Thoracic and Abdominal regions and less significant in the Cranial region. Nonetheless, despite the variability in dose reduction, the application of IR appears to be more consistent, showing a lower standard deviation compared to the conventional technique. These findings underscore the effectiveness of Iterative Reconstruction in improving the consistency of radiation doses, even if it does not always result in substantial reductions.

4. CONCLUSION

Based on the analysis performed, we observed that the most favorable results were achieved by the CT scanner that did not use Iterative Reconstruction. Interestingly, the equipment with IR application recorded higher radiation exposure rates compared to the CT scanner without this functionality. This finding is particularly relevant when considering the need to reduce patient exposure to radiation. It is essential to emphasize that the lower the radiation dose and the higher the quality of the radiographic image, the greater the patient's safety and well-being during the procedure. This study presents promising perspectives for the future of imaging exams, with a focus on improving the technologies used. This approach aims to ensure more accurate and safer diagnoses, promoting advances both in the medical field and in the well-being of patients.

Disclaimer (Artificial intelligence)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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