BJRS

BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
09-03 (2021) 01-15

SBPR
Sociedade Brasileira de Proteção Radiológica

Image quality in chest tomography employing three different equipment technologies

Pedrosa[1], K. F. S., Nogueira[2], M. S.

[1]*Instituto de Pesquisas Médicas – IPEMED - AFYA, Belo Horizonte – MG, Brasil.*

[2]*Centro de Desenvolvimento da Tecnologia Nuclear – CDTN, Belo Horizonte – MG, Brasil.*

katia_ped@yahoo.com.br e katia.silva@ipemed.edu.br

ABSTRACT

Computed tomography represents the largest portion of the population´s exposure to ionizing radiation related to medical imaging. This article aims to assess the quality of the images through the analysis of radiologists in routine chest protocols, performed at one hospital and two diagnostic imaging clinics, and employing three equipment with different technologies. A total of 1,088 criteria were analyzed with the three imaging techniques, and the average percentage of the observed structures were 95, 99 and 99% for each service. There was an excellent correlation between observers and even an absolute agreement in some cases for the most modern technologies. The three studied devices provided acceptable dose values and images with a quality close to 100%, reducing the exposure and improving the radiological protection of patients.

Keywords: Computed tomography, chest, diagnostic imaging, image quality.

ISSN: 2319-0612
Accepted: 2021-09-06

1. INTRODUCTION

Computed tomography (CT) exposure has provided a growing awareness of the possible adverse effects arising from radiation since this technique leads to the largest portion of the population being exposed to ionizing radiation related to medical imaging. [1, 2, 3, 4] Therefore, considering the frequency of these tests, it is very important to analyze the current protocols as an attempt to optimize the procedures in order to reduce radiation doses. For instance, modifications in the X-ray tube tension, pitch and slice thickness might drop the dose to the patient without affecting image quality. [5]

The tomography of the thoracic region is one of the best tools to assess calcifications [6] and responses to oncological treatments such as radiotherapy and chemotherapy among the various target regions for a CT. Also, according to ICRU 2012, it is one of the most examined anatomical regions in radiology departments [7, 8, 9,10]. Patients with alterations in chest radiographs are generally referred for a tomography exam in order to elucidate, precisely locate and clarify the extent of alterations [11].

The Standard protocols to acquire tomographic images take into account each anatomical region according to the size of a standard adult patient. Nevertheless, depending on the patient's biotype, image acquisition parameters that might be adjusted regarding the equipment manufacturer and, in many cases, the judgment of the professionals involved in this process [12]. For example, low-dose protocols employ acquisition parameters below the Standard protocol and are widely used to assess the thoracic region. Indeed, these protocols display the lowest current (mA) and voltage (kV), aiming to reduce the patient exposure to radiation, but still maintaining the diagnostic quality of the images. [3, 13]

However, the establishment of a low-dose protocol involves several factors and is directly linked to image quality. All these aspects might compromise the diagnosis and the radiological analysis of the images. [4, 7] In fact, the radiological analysis represents a vital step in this process because, even if the equipment is calibrated and displays parameters within the reference values/limits presented by the regulatory standards and compatible with all quality control tests, this evaluation also depends greatly on the visual acuity of the radiologist.

In this context, it is essential to reconcile image acquisition parameters and patient exposure with image quality. As a matter of fact, there is no way to assess image quality without analyzing patient exposure and consequently dosimetric measurements. Therefore, the volumetric dose index (C_{vol}), which is a guiding index of dose parameters in tomography, will be used as a dose reference in this work.

Given this scenario and the importance of reducing the population exposure to radiation, the objective of this study is to assess the quality of images through the analysis of radiologists in routine chest protocols employing three equipment with different technologies to evaluate the impact of the equipment technological development along the years in terms of image quality and patient exposure: (Ring Detectors 6, Model Emotion; Ring Detectors 64, Model Sensation; Ring Detectors 128, Model Somatom). The comparison of the dose levels in CT might provide future optimization proposals of these protocols, reducing the radiation dose to the patient.

2. MATERIALS AND METHODS

The work was submitted to the ethics committee to request authorization of the use of patient images, and it was approved with the identification CAAE 44515315.6.0000.5138. Before signing the Informed Consent Form (*Termo de Consentimento Livre e Esclarecido* – TCLE), participating patients were informed about the objectives of the research and that they would not be exposed to any additional risks for carrying out this study.

Chest tomography images were collected in inspiratory apnea without the use of venous contrast, employing Automatic Exposure Control (*Controle Automático de Exposição* – CAE) in all images from all services. The exclusion criterion was the presence of signs of disarrangement/significant alterations in the architecture of the lung parenchyma that would hinder or impede the radiological analysis of the anatomical structures. Thus, images with the prevalence and prognosis of some previous thoracic pathologies were not included in the study. After collecting the images, a technical analysis was performed, and the images that did not meet the research criteria, showing signs of disarrangement of the parenchyma architecture, were discarded.

Experimental measurements of C_{vol} were performed for the chest protocol in all equipment of this study. This quantity (C_{vol}) was selected to compare the equipment once the dosimetric quantity was provided by the tomographers at the end of each exam. Another quantity that also quantifies the dose in tomography is the dose-length product (DLP), which was not addressed due to its direct relation to technical parameters not analyzed in this article such as positioning and patient anatomy.

2.1. Sampling

The present study sampled 64 patients aged between 18 and 90 years - 39 female and 25 male patients. The images were collected from three diagnostic services A (a general care hospital), B and C (diagnostic imaging clinics). Thus, images were collected from 14 patients at service A, 20 patients at service B, and 30 patients at service C. The images were collected randomly according to the date criterion, and the exams were scheduled by the patients themselves during the sampling period. Also, the acquisition of images was carried out according to the routine protocol of each service.

2.2. Equipment and Protocols

The criteria for selecting the three equipment were based on the technology used over the years and the same manufacturer, ranging from older, intermediate, and more recent technology. Three radiology departments were part of this study, and the first center (labelled Service A) consisted of a general care hospital displaying an Emotion 6 tomograph. The other health services were private clinics with a Sensation 64 (Service B) and SOMATOM Definition AS+ (Service C) equipment. Details of the equipment and protocols are shown in Table 1.

Table 1. Tomographs and Protocols

Tomograph	Service A	Service B	Service C
Ring Detectors	6	64	128
Model	Emotion	Sensation	Somatom
Tension [kV]	110	120	120/140
Reference Current [mA]	70	110	91/130
Rotation time [s]	0,8	0,5	0,33
Pitch	1,5	1,0	1,2
Collimation [mm]	1,25	0,6	0,6
Slice [Cutting Thickness]	1,25	1,0	1,0

2.3. Radiological Analysis of the Images

The images were independently analyzed by three radiologists through a questionnaire based on the criteria defined by the European Protocol [14] for some important anatomical structures that must be clearly detected. The images were available in DICOM format through a PACS image archiving system on specific monitors of the same model.

Radiologists were identified as RadA, RadB and RadC observers. RadA observer was a professional with more than ten years of experience and a chest specialist, RadB observer was a professional recently specialized in radiology, and Rad C was a professional with more than ten years of experience in general radiology. Even though changing parameters is a common part of the practice of radiological analysis, observers were instructed not to change any parameter of image visualization such as size and window. The result of each analysis was collected separately, and a comparative analysis was performed between the observers to assess the disagreement between them.

2.4. Dose Values for the CT Equipment

Chest CT dose reports were used with the standard protocol of all equipment. At the same time, a pencil-type solid state detector (model 8202041 UNFORS) and a PMMA simulator (32 cm in diameter and 15 cm in length) were used to perform the measurements. The value of C_{100} was measured three times in the five points of the simulator object (four distributed in the periphery and one in the center). From this approach, the value of C_{vol} for the standard protocol of all equipment was calculated.

2.5. Statistical Analysis

The statistical analysis was performed using the hypothesis test. Also called the significance test, it might determine whether there is enough evidence in a data sample to infer that a given condition is true for the entire population [15]. In this study, it was considered "agree" when the observers visualized the anatomical structures, and "disagree" if they did not. Then, the next step for the statistical analysis was to define the hypotheses:

• Null Hypothesis (H_0): It is the hypothesis considered as the initial hypothesis [statement] being tested. Based on the sample data, the test determines whether we should reject the null hypothesis, and, in this work, H_0 (proportion of dissenters) was defined as $H_0 = 0.01$, which means that the agreement index between the observer readings is 99%. Thus, if the proportion of dissenters is very low, it is understood that they agree.

• Alternative hypothesis (H_1): In this study, H_1 was defined as > 0.01, which means that the agreement rate between the observer readings is less than 99%.

For this work, a confidence index of 95% CI was defined and, therefore, the alpha value or cutoff value to test the hypotheses was $\alpha = 0.05$. The alpha value is the test parameter that will define whether H_0 will be accepted or rejected.

Using Minitab, a p-value was calculated to determine the hypothesis. If the p-value is less than or equal to the significance level, which is a defined cutoff point, the null hypothesis can be rejected. Therefore, if p-value is less than 0.05 (value of α), the zero hypothesis (H_0) will be rejected and a disagreement in that analyzed criterion will be considered [13]. Thus, we proceeded to organize the data on the disagreement index between the observers.

3. RESULTS AND DISCUSSION

3.1. Sampling

The present study consisted of a sample of 64 patients aged between 18 and 90 years composed of 39 female patients and 25 male patients. Images were collected from 14, 20 and 30 patients for services A, B and C, respectively. As a hospital, service A provided a smaller sample due to the difficulty of collecting patients without disarrangement of the anatomical structure in the parenchyma. On the other hand, service C furnished more samples because of the greater demand for this examination in this clinic. After signing the consent form, a total of 16 patients were excluded from this study for presenting significant anatomical changes in the lung parenchyma. All analyzed criteria and their respective percentages in each service are shown in Tables 2A and 2B.

3.2. Dose values of the CT equipment

The results found from the experimental measurements of C_{vol} in the tomographs were 18.67 mGy, 6.58 mGy and 5.81 mGy at services A, B and C, respectively. They were compared with the values provided by the equipment of 19.58 mGy, 11.10 mGy and 9.10 mGy at services A, B and C, respectively. All experimental values were lower than the ones reported by the equipment, and it is also possible to notice a dose drop tendency according to the technological evolution of the equipment. Tomography sampling consisted of three Siemens multi-detector devices. The studied equipment displayed varied technologies with 6, 64 and 128 detectors. Such trend was observed for both the experimental and reported values demonstrating that, though the image quality is considered good, more modern technologies were able to employ significantly lower doses. [16, 17]. It is important to point out that image quality is influenced by several parameters such as FOV (Field of view), isocenter, resolution matrix, algorithm, current, voltage, collimation and pitch.

The American Association of Physicists in Medicine (AAPM) considers a weight range for C_{vol} values, placing an average patient of approximately 70-90 kg in the range of 8-16 mGy. Considering this value as the Diagnosis Reference Level (DRL) for this study, it can be observed that the 6-detector ring tomograph (Service A) presented a value approximately 16% superior. This equipment periodically undergoes corrective maintenance, and the software is constantly updated. However, this is a technology that is no longer produced by the manufacturer and every repair is performed with re-adapted parts. Furthermore, even though the CT scan protocol from service A presents a lower voltage concerning the others, the current-time product is higher.

3.3. Statistical analysis

The criteria with the lowest percentage of visualization (Tab. 3) were 2.2 (middle third), 5 (secondary lobular structures, such as centrilobular arterioles), 7 (good definition of the pleuromediastinal edge) and 8 (definition of the pleuromediastinal edge). It is important to consider that these are very small structures, and the images were reformatted with an interval of 25mm between them, which may have allowed partial visualization or even prevented visualization of anatomical structures. Moreover, item 2.2 (middle third) is a region close to the heart and, due to cardiac contractions, can cause involuntary movement artifacts, making the structures in this region difficult to observe.

Using the Minitab software for the hypothesis test, the p-value = 0.05 was calculated, and values less than 0.05 were considered disagreement about the visualization of anatomical structures regarding this criterion. Thus, the p-values found for the three observers are shown in Table 3 for each evaluated service evaluated, and the points of disagreement between the observers are marked in bold and gray.

The profile of the sample was quite different with service A presenting a smaller number of patients since it was a hospital, implying in many tests of patients with disarrangement of the anatomical structure in the parenchyma. The sample from service C was larger due to the demand for this test in this clinic. In all services, access to patients was according to the schedule made by the patient.

Table 2A. Percentage of the observed criteria (lung window) (1)

N	Criteria	Service A (%)			Service B (%)			Service C (%)		
		Rad A	**Rad B**	**Rad C**	**Rad A**	**Rad B**	**Rad C**	**Rad A**	**Rad B**	**Rad C**
					Lungs					
1	Visualization of lung anatomy	92.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2	Lung parenchyma	92.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2.1	Upper Third	92.9	100.0	92.9	100.0	100.0	100.0	100.0	96.7	100.0
2.2	Middle Third	85.7	100.0	100.0	100.0	100.0	100.0	100.0	96.7	100.0
2.3	Lower Third	92.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3	Lung fissures	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4	Lung vessels	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4.1	Lung vessels L or M	100.0	92.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0
5	Lobular structures and arterioles	100.0	100.0	100.0	100.0	90.0	100.0	100.0	83.3	100.0

Table 2B. Percentage of the observed criteria (lung and mediastinum window) [1]

N	Criteria	Service A (%)			Service B (%)			Service C (%)		
		RadA	**RadB**	**RadC**	**RadA**	**RadB**	**RadC**	**RadA**	**RadB**	**RadC**
					Lungs					
6	central bron	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
6.1	main bron-chi	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
6.2	Lumbar bronchi	92.86	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
6.3	Seg bronc	92.86	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
7	pleural def-inition	100.00	85.71	100.00	100.00	65.00	100.00	100.00	83.33	100.00
8	Def. parenc border	100.00	100.00	100.00	100.00	100.00	100.00	100.00	93.33	100.00
						Mediastinum				
4.1	L or M pulm vese	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	96.67
6.1	main bron-chi	100.00	92.86	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1] Lung window is the term used in practice for the image reconstructed with a specific algorithm showing a greater definition of anatomical structures and displaying the window, which is the variation of the image gray tones, varying image brightness and contrast, also specific for visualization of the structures of the lung parenchyma. The Mediastinum window is the term used for the image reconstructed with an algorithm that smooths the image, especially to show larger anatomical structures. The mediastinum window shows structures in medium shades of gray.

For the evaluation of image quality, 238, 340 and 510 criteria were analyzed in services A, B and C, respectively, totaling 1,088 criteria (Table 3).

Table 3. Disagreement between observers of each service = <0,05

N°	Criteria	Service A			Service B			Service C		
		Rad A/B	**Rad B/C**	**Rad A/C**	**Rad A/B**	**Rad B/C**	**Rad A/C**	**Rad A/B**	**Rad B/C**	**Rad A/C**
		p-value	**p-value**	**p-value**	**p-value**	**p-value**	**p-value**	**p-value**	**p-value**	**p-value**
	Lungs									
1	Pulmonary Visualization	0.13	1.00	0.07	1.00	1.00	1.00	1.00	1.00	1.00
2	Lung Parenchyma	0.13	1.00	0.07	1.00	1.00	1.00	1.00	1.00	1.00
2.1	Upper third	0.13	0.13	**0.01**	1.00	1.00	1.00	0.26	0.26	1.00
2.2	Middle third	**0.01**	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
2.3	Lower third	0.13	1.00	0.07	1.00	1.00	1.00	0.26	0.26	1.00
3	Lung fissures	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	Lung Vessels	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4.1	L or M Pulmonary Vessels	0.13	0.13	0.07	**0.00**	**0.00**	1.00	**0.00**	**0.00**	1.00
5	Lobular Struct	1.00	1.00	1.00	**0.02**	**0.02**	1.00	**0.00**	**0.00**	1.00
6	Central Bronchial Tree	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6.1	Main bronchi	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6.2	Lobar bronchi	0.13	1.00	0.07	1.00	1.00	1.00	1.00	1.00	1.00
6.3	Segmental bronchi	0.13	1.00	0.07	1.00	1.00	1.00	1.00	1.00	1.00
7	Good Def. Pleural Edge.	**0.01**	**0.01**	0.00	**0.00**	**0.00**	1.00	**0.00**	**0.00**	1.00
8	Good chest wall definition	1.00	1.00	1.00	1.00	1.00	1.00	**0.00**	**0.04**	1.00
	Mediastinum									
4.1	Mediast L or M	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.26	0.26
6	Mediastinum/BronTree	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6.1	Mediast/Bronchi	0.13	1.00	0.34	1.00	1.00	1.00	1.00	1.00	1.00

For the mediastinum, only items 4.1 and 6.1 were considered (large or medium pulmonary vessels and main bronchi, respectively) because the reconstruction algorithm does not clearly permit for the other criteria.

Images were reformatted with an interval of 25 mm between them, which might have allowed partial visualization or even prevented visualization of anatomical structures. Item 2.2, "Middle Third", is a region close to the heart and due to cardiac contractions, that can cause artifacts of involuntary movements, troubling the visualization in this region and contributing to increase the divergence of interpretation.

The results for the total percentage of observed criteria were 95%, 99%, and 99% for services A, B, and C, respectively. These values are consistent with the technology of the equipment in this study, as also demonstrated by Móran, 2004 [18], who reported the percentage of observed criteria between 93-98% for lower technology equipment. The service with the lowest percentage of visualization of the criteria was service A. This equipment displayed an older technology with a lower resolution matrix, which can directly interfere with the visualization of small structures. Also, the image acquisition time was superior when compared to the other equipment. A longer examination time may generate movement artifacts in the image, especially since the profile of hospitalized patients may be more debilitated compared to patients who undergo elective exams.

As reported by Souza (2018) [19], the image quality is influenced by several parameters such as field of view (FOV), isocenter, resolution matrix, image reconstruction algorithm, current, voltage, collimation and pitch. Nonetheless, the most important guideline is to follow the Diagnostic Reference Level (DRL).

In this study, the highest agreement rate was between RadA/RadC observers in all services, especially in services B and C, with an absolute agreement between them. This condition might be explained by the fact that the equipment of services B and C presented a more modern technology with better image resolution, and, also, by the fact that these professionals were more experienced. [20,21]

The highest levels of disagreement occurred in criteria 4.1, 5, 7 and 8, which may reflect the degree of demand of each observer for the partial visualization of the structures. For criteria 3, 4, 6 and 6.1, there was absolute agreement for all services and among all observers, indicating an image quality of 100% for these criteria.

Finally, an important point to be considered is the level of personal demand of each observer. Even if they were instructed to proceed in the same way regarding the non-manipulation and alteration of the images, they could judge the same criteria in different ways, especially in cases of partial visualization of the structures. Another relevant point is the experience of these professionals, as the knowledge acquired in their professional career interferes with the interpretation of images, as reported by Antunes V. B., et al. (2010) [22]. It is also important to emphasize that in clinical practice, many of the exams are evaluated by general radiologists and not by thoracic radiologists with vast experience in the interpretation of images in this anatomical region.

4. CONCLUSION

The lung parenchyma analysis by computed tomography is not replaceable by any other diagnostic method due to the quality of the image and the provided information by this method, demonstrating its great radiological importance. In the evaluation of image quality criteria, it was concluded that the three services provided images with quality higher than 95% in one service and 100% in the others. Regarding dose-related values, the experimental values of the dosimetric quantity C_{vol} were consistent with the values provided by the equipment and with their technology. Also, a trend in the reduction of dose values was noticed according to the technological evolution of the equipment. Thus, considering the assessment of image quality to be satisfactory, the technical parameters can be changed for a possible dose reduction to create a low-dose protocol and consequent improvement in the radiological protection of the patient, producing a social benefit.

5. ACKNOWLEDGMENT

The authors thank Professor Dr. Alberto Avelar Barreto (in memoriam), the Nuclear Technology Development Center (CDTN), the radiologists at the Faculty of Medicine of UFMG and Axial Inteligência Diagnóstica, and CAPES for the financial support which was essential for this work.

REFERENCES

[1] PINA, *et al*. **Criação de um indicador eletrônico para acompanhamento de dose no setor de Tomografia Computadorizada**. Brazilian Journal of Radiation Sciences. Braz. J. Rad. Sci. 2020. 08-03 (2020) 01-14.

[2] AIEA. TSA -3 Protección radiológica en lãs Exposiciones Médicas RLA 9057 / RLA 9067. **Programa Regional Del OIEA para América Latina, 2007- 2013.**

[3] KUBO, T. *et al*. **Standard-dose vs. low-dose CT protocols in the evaluation of localized lung lesions: Capability for lesion characterization**—iLEAD study. European Journal of Radiology Open. [2016 a] 67–73. Disponível em: https://www.ejropen.com/article/S2352-0477(16)30007-7/pdf. Acesso: mar. 2019.

[4] KUBO, T. *et al*. **Low dose chest CT protocol [50 mAs] as a routine protocol for comprehensive assessment of intrathoracic abnormality**. European Journal of Radiology Open Volume 3 [2016 b] 86–94. Disponível em: https://www.ejropen.com/action/showPdf?pii=S2352-0477%2816%2930009-0. Acesso: abr. 2019.

[5] SOUZA, G. S.; FRONER, A.P.P.; SILVA, A.M.M.; **Doses em tomografia computadorizada de crânio: impacto do uso do controle automático de exposição.** Revista Brasileira de Física Médica. 2017; 11[2]:21-24

[6] ZAMPIERI, J.F.; PACINI, G.S.; ZANON M.; *et al*. **Calcificações torácicas na ressonância magnética: correlação com a tomografia computadorizada.** J Bras Pneumol.;45[4]: 2019e20180168.

[7] ICRU - International Commission on Radiation Units and Measurements. **Radiation Dose and Image-Quality Assessment in Computed Tomography, ICRU Report 87**, Journal of the ICRU, v. 12, No 1, 2012. Report. 87. Disponível em: https://icru.org/content/reports/radiation-dosimetry-and-image-quality-assessment-in-computed-tomography-icru-87. Acesso: mar.2019.

[8] SOUZA, G.S.; FRONER, A.P.P.; SILVA, A.M.M.; **Levantamento de Doses em Tomografia Computadorizada em Protocolos de Crânio e Tórax**. Revista Brasileira de Física Médica. 2016;10[3]:34-38.

[9] TORRES, P.P.T.S.; RABAHI, M.F.; MOREIRA, M.A.C.; *et al*. **Avaliação tomográfica das doenças fúngicas no** tórax**: abordagem por padrões e sinais**. Radiol Bras. 2018 Set/Out;51[5]:313–320. Disponível em: http://dx.doi.org/10.1590/0100-3984.2017.0223. Acesso: mai 2020.

[10] NOSCHANG, J.; GUIMARÃES, M.D.; TEIXEIRA D.F.D.; *et al*. **Novas técnicas no diagnóstico por imagem do tromboembolismo pulmonar**. Radiol Bras. 2018 Mai/Jun;51[3]:178–186.

[11] SODICKSON, A.; *et al*. **Recurrent CT, cumulative radiation exposure, and associated radiation-induced cancer risk from CT of Adults. Radiology**. Boston. Volume 251: Number 1—April 2009. Disponível em: https://pubs.rsna.org/doi/pdf/10.1148/radiol.2511081296. Acesso: jan. 2019.

[12] AAPM - American Association of Physicists in Medicine. **The Measurement, Reporting, and Management of Radiation Dose in CT. College Park, MD. 2008**. [AAPM Report. 96]. Disponível em: https://www.aapm.org/pubs/reports/RPT_96.pdf. Acesso: mar 2019.

[13] DORNELES, C.M.; PACINI, G.S.; ZANON, M.; *et al*. **Ultra-low-dose chest computed tomography without anesthesia in the assessment of pediatric pulmonary diseases**. J Pediatr [Rio J]. 2020; 96:92-9.

[14] KHAN *et al*. **Comparison of radiation dose and image quality:320-MDCT versus 64-MDCT coronary angiography**. AJR Am J Roentgen vol. 2011.

[15] ALVES E CALDAS. **Determinação da dose em pacientes submetidos a exames de tomografia computadorizada de abdome em um serviço de radiologia e diagnóstico por imagem**. Brazilian Journal of Radiation Sciences. Braz. J. Rad. Sci. 08-03 (2020) 01-18

[16] EUR - European Guidelines on Quality Criteria for Computed Tomography, Luxembourg. **European Commissions' Radiation Protection & the Office for Official Publications of the European Commission. 2004.**

[17] MINITAB. Suporte ao **MINITAB 17.** Disponível em: https://support.minitab.com/pt-br/minitab/19/. Acesso em: 01 jun. 2017.

[18] MÓRAN, L.M.; RODRIGUEZ, R.; CALZADO, A. *et al*. **Image quality and dose evaluation in spiral chest CT examinations of patients with lung carcinoma.** The British Journal of Radiology, 77, 839–846 2004.

[19] SOUZA, G.S.; LANFREDI, M.P.; SILVA, A.M.M.; **Parâmetros de aquisição em tomografia computadorizada para pacientes pediátricos: uma revisão bibliográfica.** Revista Brasileira de Física Médica. 2018;12[3]:30-34.

[20] ALMEIDA, R.F.; *et al*. **Padrões de tomografia computadorizada de alta resolução na doença pulmonar intersticial [DPI]: prevalência e prognóstico**. J Bras Pneumol. 2020; 46 [5]: e20190153. Disponível em: http:// dx.doi.org/10.36416/1806-3756/e20190153. Acesso em: 20 jun. 2020

[21] BRITO, M.C.B.; OTA M.K.; LEITÃO FILHO, F.S.S.; *et al*. **Concordância entre radiologistas na quantificação de bronquiectasias pela tomografia computadorizada de alta resolução**. Radiol Bras. 2017 Jan/Fev;50[1]:26–31.

[22] ANTUNES, V. B.; MEIRELLES, G.S.P.; JASINOWODOLINSKI, D.; *et al*. **Concordância entre observadores no diagnóstico das doenças pulmonares intersticiais por imagens de TCAR**. J Bras Pneumol. 2010;36[1]:29-36.