Original Article

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Pediatric computed tomography dose optimization in a general hospital

Otimização de dose em tomografia computadorizada pediátrica em hospital geral

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Abstract

This work presents a methodology for the optimization of protocols applied to pediatric patients who underwent brain and chest computed tomography examinations. The implementation of this methodology aims to reduce the dose of ionizing radiation delivered to patients and the consequent risk associated with radiation, without decreasing the diagnostic image quality. The comparison between the results of $CTDI_{vol}$ (computed tomography dose index) and DLP (dose-length product) dosimetric quantities before the optimization process and their corresponding results after the implementation of the optimization process was done through boxplot graphs. It is noteworthy that the implementation of this methodology allows reductions in the range between 18 and 50% of the dosimetric values evaluated in this study. In addition, the case of brain computed tomography scans, in which the cohort of the evaluated patients is larger, is a highlight, which should also reflect in the reduction of the absorbed radiation dose by this particularly important group of patients.

Keywords: optimization; pediatrics; computed tomography.

Resumo

Neste trabalho, apresenta-se uma metodologia para otimização de protocolos aplicados a pacientes pediátricos submetidos a exames de tomografia computadorizada de crânio e tórax. A implementação desta metodologia tem por objetivo reduzir a dose de radiação ionizante entregue aos pacientes e o consequente risco de radiação associado, sem diminuir a qualidade da imagem diagnóstica. A comparação entre os resultados das grandezas dosimétricas $CTDI_{vol}$ (índice de dose de tomografia computadorizada) e DLP (produto dose-comprimento) anteriores à implementação da otimização e os resultados provenientes do processo de otimização foi realizada por meio de gráficos tipo *boxplot*. Nota-se que a implementação desta metodologia possibilita reduções entre 18 e 50% nos valores das grandezas dosimétricas avaliadas neste trabalho. Destaca-se o caso dos exames de tomografia computadorizada de crânio, nos quais a coorte de pacientes avaliada foi maior, o que deve refletir também na redução da dose de radiação absorvida por este grupo particularmente importante de pacientes.

Palavras-chave: otimização; pediatria; tomografia computadorizada.

1. Introduction

According to the publication of the International Atomic Energy Agency (IAEA) of Human Health Sciences (HHS) 24 — Dosimetry in Diagnostic Radiology for Pediatric Patients[1] —, dosimetry for pediatric patients undergoing diagnostic radiology procedures requires special consideration in addition to the dosimetry methods used for adult patients. The importance of dosimetry for this group of patients is more delicate than for adults, considering their longer life expectancy and greater risk from radiation exposure. This risk is due to relative radiosensitivity of various body tissues that vary according to sex and age. In addition, collection and analysis of data for these patients are complex, especially due to the large and continuous range of patients with distinct sizes present in the pediatric population.

The examinations of a pediatric patient differ from that of adults in many ways, including different technical factors, beam quality and, ideally, different radiological equipment. One should also consider the type of performed tests and the skill set of the personnel needed to perform these procedures successfully[2,3]. Campaigns, such as Image Gently[4,5],

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Image Wisely[6] and Latin Safe (http://latinsafe.org/global/), are fundamental for clarifying professionals and parents about the importance of an adequate balance between dose and image quality, and international approaches such as the Bonn Call for Actions are decisive on the definition of strategies for reaching these goals[7,8].

The main purpose of studying doses delivered to patients undergoing diagnostic imaging procedures is associating the dose of ionizing radiation with possible health risks[9]. It is a very challenging task, since the dose to which the patients are submitted is subject to considerable oscillations given the great variation of weight and size of this group of patients.

Analyzing dose patterns in populations of similar size and age becomes relevant. Thus, we adopted the quantitative parameter of Dose Reference Levels (DRLs), which is also used to optimize exposure level[10]. The DRLs state that about 75% of the facilities must work at levels following the established DRL (equal or lower), while the remaining 25% of them must exceed DRLs[11,12].

Dosimetric quantities for use in the computed tomography (CT), such as CT dose index (CTDI) and dose-length tomography (DLP), may be used as tools for identifying excessive or insufficient exposures for the diagnostic images, because they are associated with the doses delivered to the patients. The pattern identification of these quantities is a milestone of the optimization process in the pediatric population that undergoes CT procedures, considering that the dose absorbed by the patient is not a trivial task[13-16].

2. Materials and Methods

This paper was carried out as part of the International Atomic Energy Agency (IAEA) Coordinated Research Project (CRP E2.40.20), entitled "Evaluation and Optimizations of Pediatric Imaging", which consists of a consortium of 10 countries for the study of dose optimization in diagnostic procedures for pediatric patients. The Radiation Dosimetry and Medical Physics Group of the Institute of Physics of the Universidade de São Paulo (IF/USP) acts as the Brazilian representative in this Coordinated Research Project (CRP) in the area of pediatric CT examinations. This group has been working for more than 10 years in a Quality Assurance Program (QA) at the Institute of Radiology of the Clinical Hospital of the School of Medicine (INRAD/HC/FM/USP) of USP, where data were collected and the optimization process was implemented[17].

The paper was divided into two phases:

- phase 1: data collection of non-optimized examinations;
- phase 2: optimization in pediatric protocols.

2.1. Phase 1: data collection

In phase 1 of the study, a survey was performed with relevant information on diagnostic imaging tests performed in pediatric patients. The first step was to define four age groups to be correlated into the surveyed database. The age groups were defined as:

- 0–1 year old;
- 1–5 years old;
- 5–10 years old;
- 10–16 years old.

The ideal number of patients for each age group was stablished as 20. Initially, one CT equipment (Philips — Brilliance 64) of the facility was prioritized, since most of the pediatric examinations are performed in this machine. The CT data collection corresponding to this piece of equipment was done using DICOM header information from the INRAD database after the patients' anonymization process[18]. The surveyed information included demographic data, such as age at the examination, protocol name, examined body region (brain or thorax). It also included technical quantities, such as voltage (kVp), average/effective mAs, scan length, DLP and CTDI, each per phase[19]. Finally, data collection also included an image quality evaluation corresponding to the following criteria:

- unacceptable image quality (it could not diagnose and a rescan would be requested);
- borderline acceptable image quality (it can diagnose, but it would not welcome images of this quality in the future);
- acceptable image quality (it can diagnose and would welcome images of this quality in the future).

The classification of each examination according to the abovementioned criteria was done by an experienced radiologist.

2.2. Phase 2: optimization process

This paper was focused on protocol optimization of brain and chest CT procedures. In phase 2, the data collected in phase 1 were used for proposing optimized protocols aiming to reduce doses in CT pediatric patients, without significant loss in the image quality.

The first strategy was to compare the configuration of the collected data with similar studies published by the American Association of Physicists in Medicine (AAPM). It suggested that the protocols were published in the context of the Alliance for Quality CT for routine pediatric chest and brain CT[20]. Figure 1 shows a flowchart listing the steps conducted for the optimization process of chest and brain pediatric CT.

The radiologist in charge and the radiographer checked the proposed optimized protocols and suggested some changes. The first comment of the radiographers was that protocols were with high doses; therefore, they would try some lower mAs values than those suggested by the AAPM.

The medical physicist and radiographer in charge have adapted the protocols for some age groups for brain CT (0–1, 1–2, 2–6, 6–16, and 16–20 years old) in axial mode and one protocol for helical mode, which is used when 3D reconstructions are necessary. For the chest CT, only three age groups (0–1, 1–10 and 10–15 years old) were chosen in the helical mode. The facility radiographers were trained on the new protocols, which were left together in the same

CT console screen with the adult's protocols. In addition, they started using them in their routine exams.

After some weeks, the medical physicist responsible for the protocol introduction checked its adoption in the regular routine and made some minor adjustments. During the implementation of the new protocols, some radiologists asked to modify parameters, complaining about the noise or other image quality loss. The new images were also evaluated following the same criteria used in phase 1.

Another intervention was done, separating the pediatric from adult protocols, and the medical physicist monitored some pediatric examinations for training the whole team of radiographers, asking for technical question or other suggestions. In order to simplify the choice of the adequate protocols by the radiographers, the monitor screen of the CT equipment console was adapted considering the specificities of the pediatric patients and a color code (Figure 2).

3. Results

The parameters used in the acquisition of brain and chest images before the optimization process were collected in phase 1 of this study. The results are presented in Figures 3 and 4 as boxplot graphs, in which each age group is represented by a color.

Still in phase 1, the images were evaluated as to their quality. For the brain exams, only the 0–1 age group had images evaluated as excellent (about 30%); therefore, this group of patients had a certain potential for optimization. Regarding the chest exams, around 20% of the total images were evaluated as excellent, which made the optimization a relevant process.

In phase 2, the first results presented the dose reductions without perceptive loss in the image quality of these two general exams. The radiologist in charge for the head and neck exam observed a small degradation in the detail structures. The medical physicist contacted the radiographer to make the necessary changes in this protocol. A preliminary global view of the effects of the optimization process is shown in Figures 5 and 6 for brain and chest CT, respectively. They show the comparative results for $CTDI_{vol}$ quantity for each age group. Considering the third quartile as a dose reference level, a reduction of more than 40% in the $CTDI_{vol}$ was achieved for patients aged 5–16 years old, while for the youngest group (0–5 years old), the reduction was about 65% for brain exams. For chest exams, the most expressive dose saving was for the 0–1-year-old group of 18%.

4. Discussion

Results of the DLP quantity comparison before and after the optimization process are shown in Figures 7 and 8. After assessing the third quartile values for the DLP after the optimization process, there was a reduction of more than 50% in the age group from 0 to 5 years old, and 37% for patients aged 5 to 16 years old who underwent brain CT. For patients who underwent chest CT, the most significant reduction was 18% in the group aged 5–10 years old.

When observing the comparative graphs for brain CT, there was a significant reduction of the CTDI and DLP parameters, as well as a decrease in the range between the maximum and minimum values recorded for these parameters. By doing this analysis for the chest examinations, the reduction of the CTDI and DLP parameters is verified only in some of the age groups. This behavior can be attributed

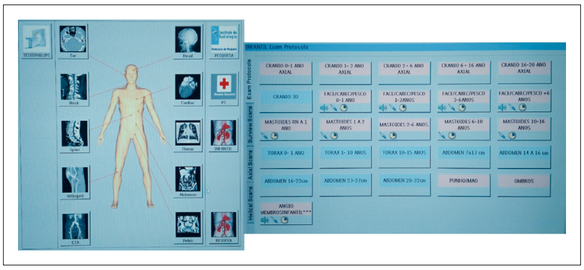

Figure 2. Adapted screens of the computed tomography equipment considering the specific pediatric protocols.

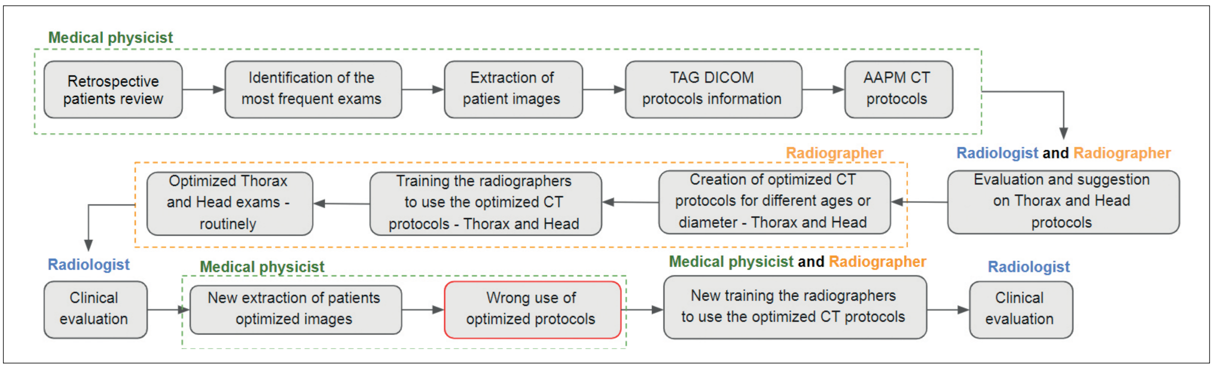

Figure 1. Flowchart listing the steps conducted for the optimization process of chest and brain pediatric computed tomography by the Brazilian participants.

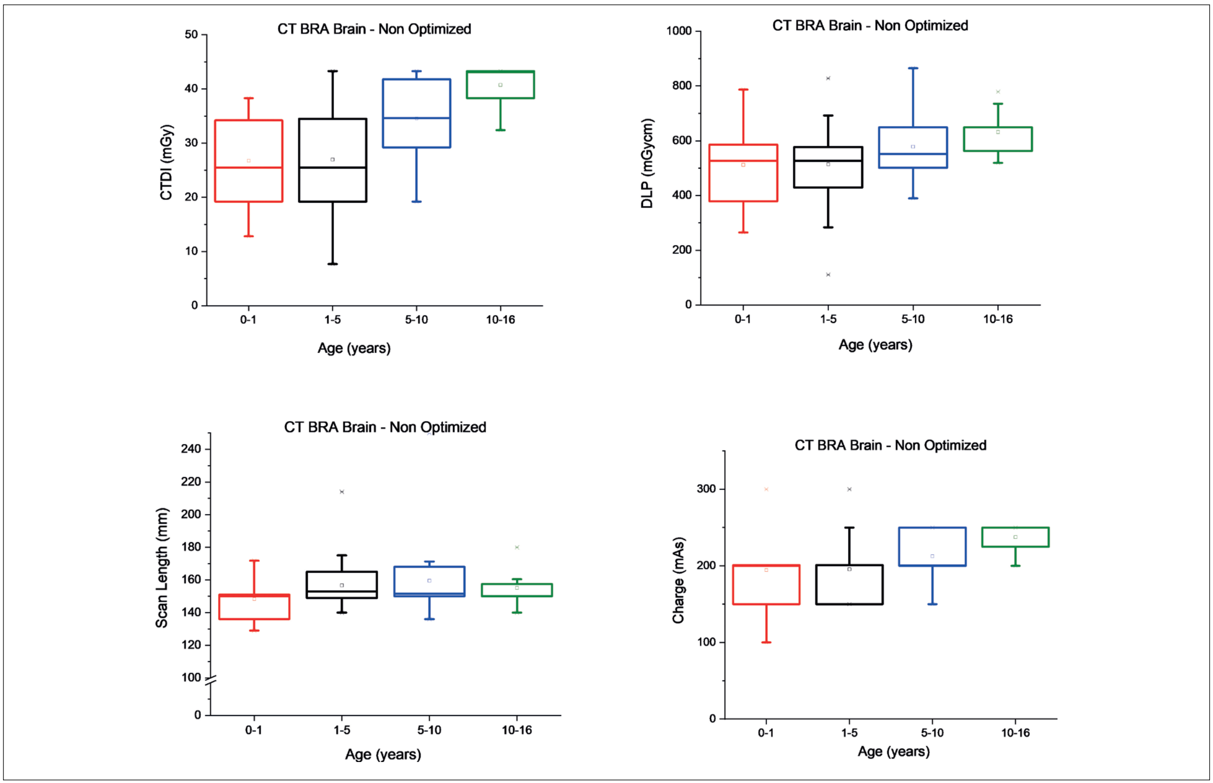

Figure 3. Results of non-optimized computed tomography dose index (CTDI), dose-length product (DLP), scan length and charge parameters for the studied image groups for brain computed tomography (CT).

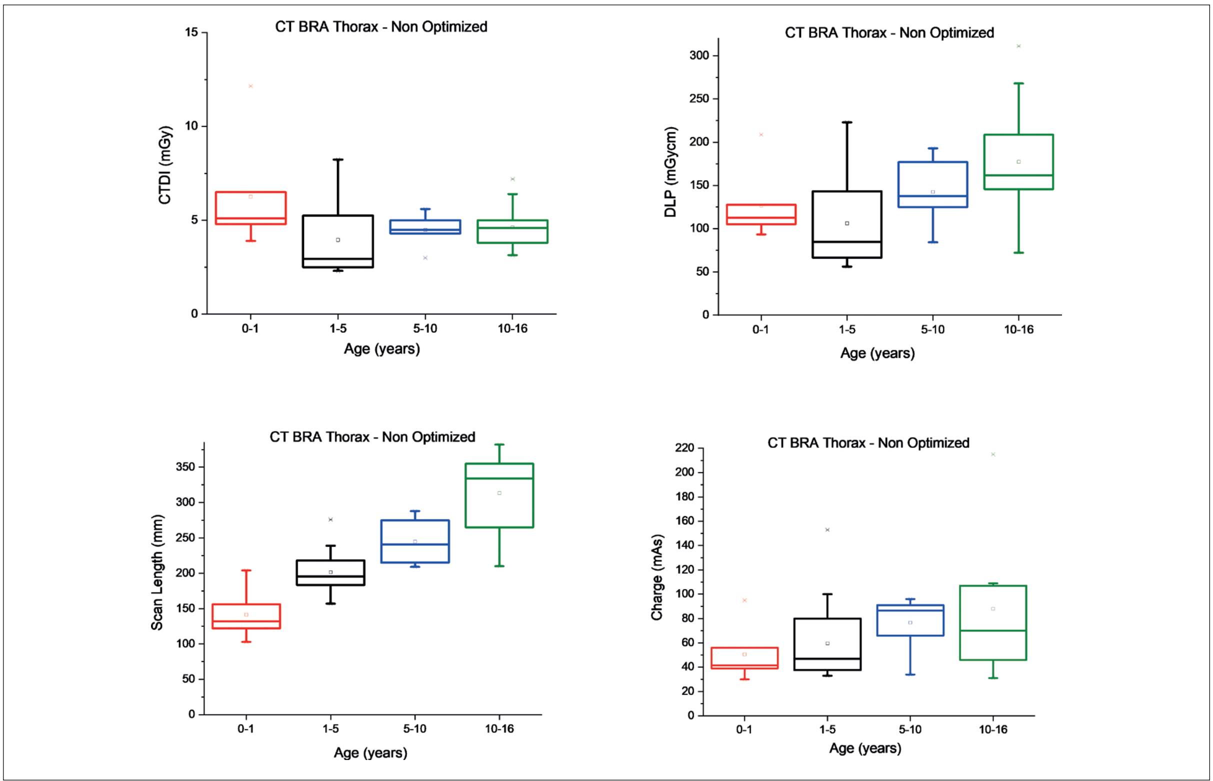

Figure 4. Results of non-optimized computed tomography dose index (CTDI), dose-length product (DLP), scan length and charge parameters for the studied image groups for chest computed tomography (CT).

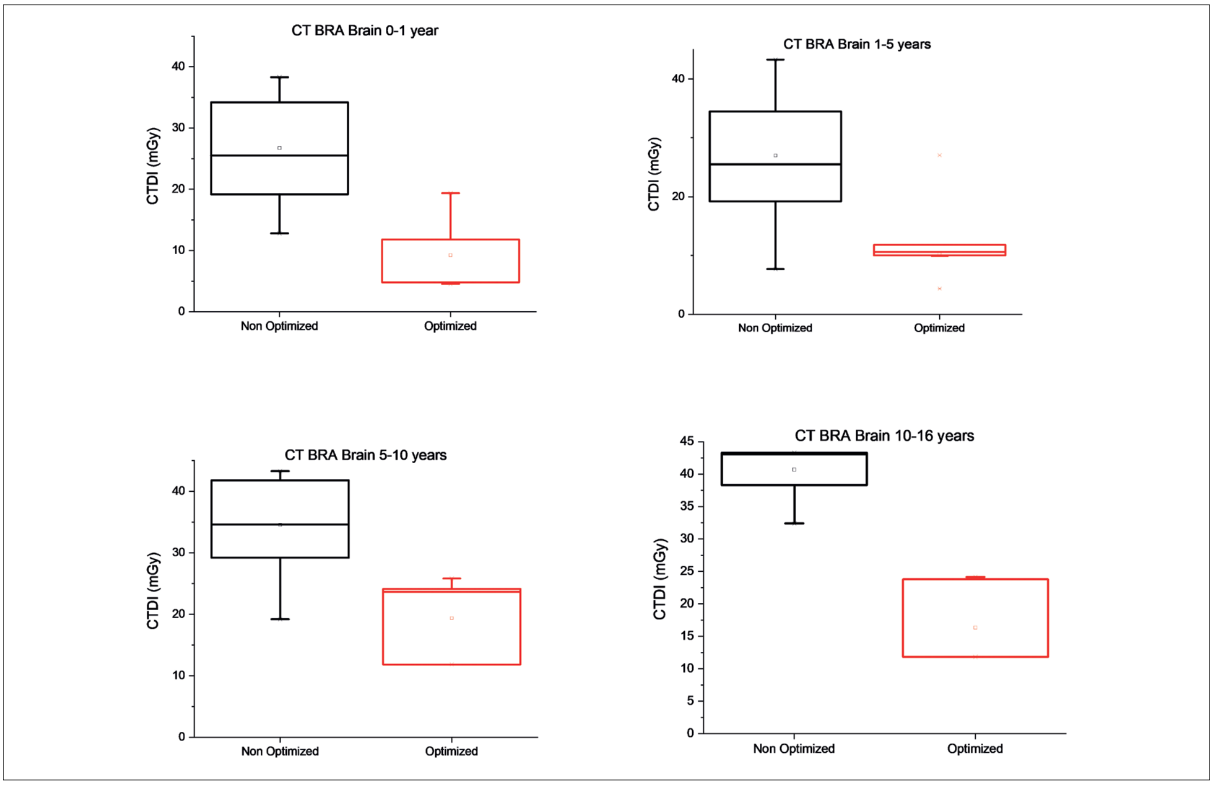

Figure 5. Comparative results of the optimized and non-optimized computed tomography dose index (CTDI) results for the studied image groups regarding the brain computed tomography (CT).

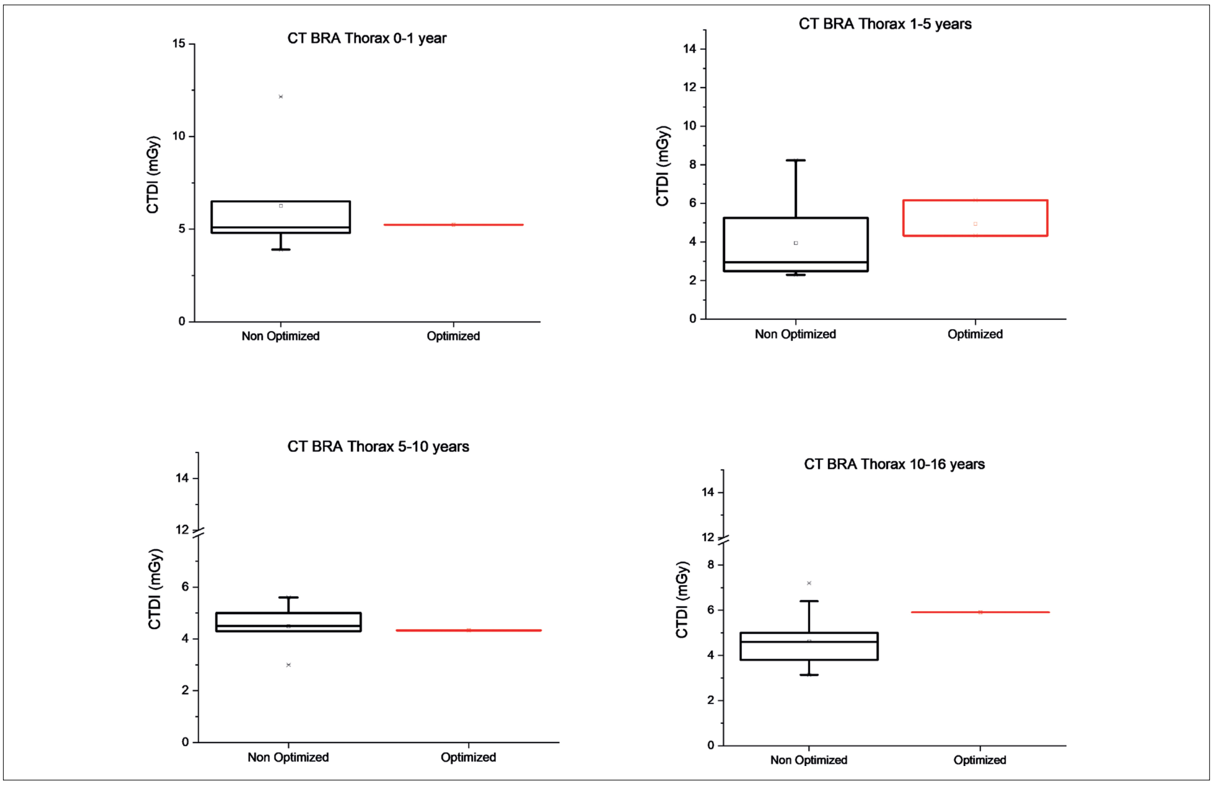

Figure 6. Comparative results of the optimized and non-optimized computed tomography dose index (CTDI) results for the studied image groups for chest computed tomography (CT).

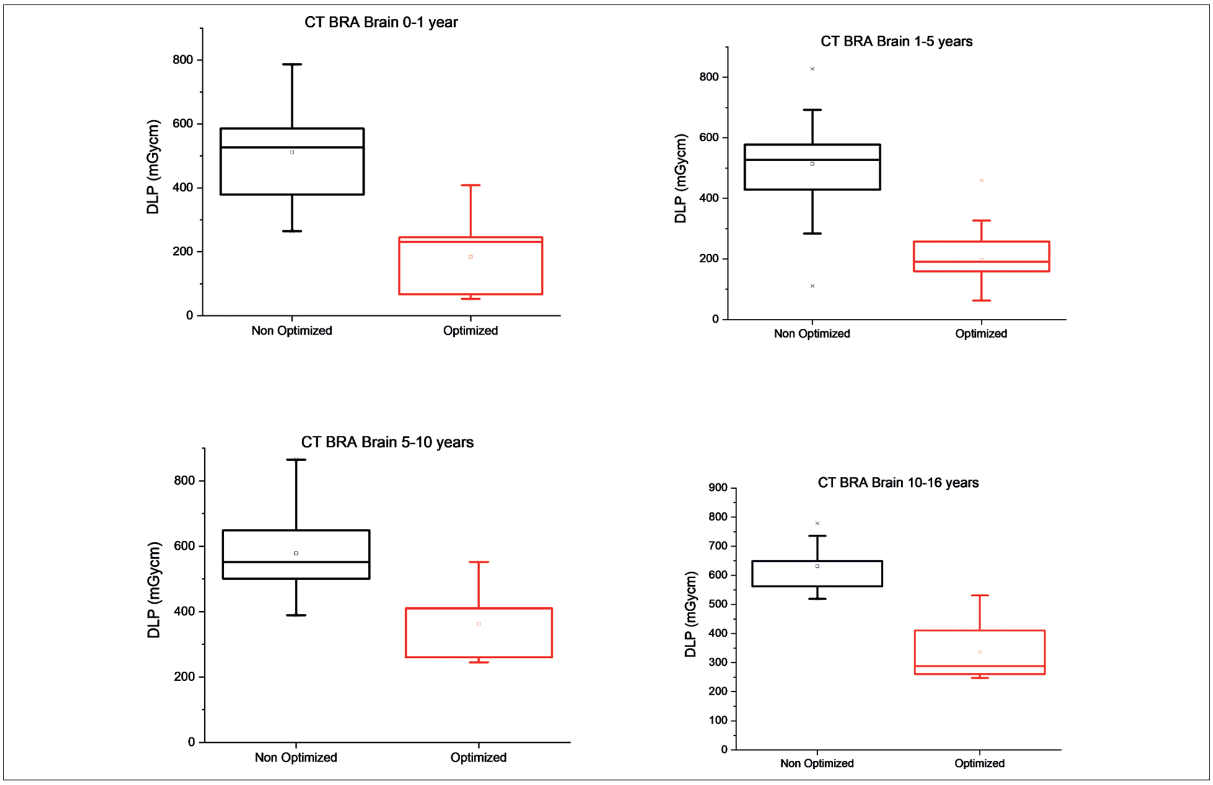

Figure 7. Comparative results of the optimized and non-optimized dose-length product (DLP) results for the studied image groups regarding the brain computed tomography (CT).

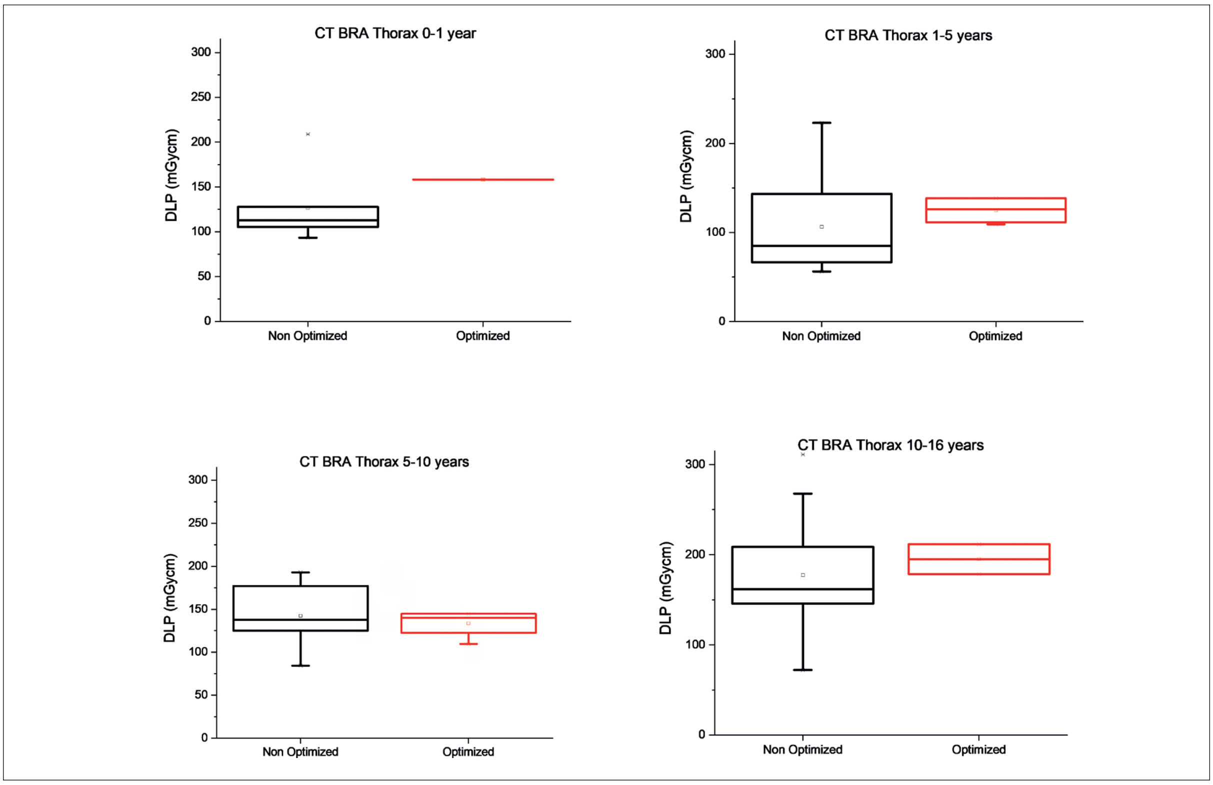

Figure 8. Comparative results of the optimized and non-optimized dose-length product (DLP) results for the studied image groups for chest computed tomography (CT).

to the small chest examination cohort, in which the largest group has six patients from aged 1 to 5 years.

5. Conclusion

The study of dosimetry applied to pediatric patients is of paramount importance, especially regarding the identification of procedures with potential for radiation dose optimization. In conclusion, the methodology described in the present study is adequate to reduce the dose absorbed by pediatric patients who underwent brain and chest CT examinations without significant loss of image quality. In addition, the optimization of the procedures is a continuous process. We expect this paper to encourage facilities to optimize their CT protocols for pediatric patients.

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