

# Method of Reducing the Radiation Dose to the Paediatric Age Groups in Computed Tomography

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## A B S T R A C T

**Introduction:** In many clinical scenarios, Computed Tomography has a dramatic evolution which has drastically improved the diagnostic performance and enhanced its field of application. Due to its increased usage nowadays, children are at higher risk of radiation-induced cancer compared to adults which has led to increased biologic sensitivity to ionizing radiation which has resulted in more time for potential radiation-induced cancer to develop. Hence, the aim of the present study was to analyse the method among paediatrics to reduce radiation dose in computed tomography of brain.

**Material and methods:** The present study was a retrospective study which was conducted among pediatric population which was further subdivided in three groups based on patient age as: 0–4, 5–9, and 10–14 years. Various parameters such as tube voltage, tube current, tube rotation time, acquisition mode (sequential or helical), beam pitch (for helical CT studies), detector configuration, automated tube current modulation (enabled or disabled), CT dose index (CTDI), and dose-length product (DLP) were used. For analysis of image, examination consisted of scout images plus a stack of 2.5- or 3-mm-thick axial images were analysed in the study.

**Results:** In the present study, out of 100 subjects, 34 and 38 subjects were scanned with the help of 350 mAs and 120 kVp and 28 were scanned with the help of 200-300 mAs. It was found that in the age group 0-4 years; tube current time was kept at 240 mAs and 57.9 kV followed by 280 mAs and 61.2 kV for 5-9 years. For the 10-14 years age group, 310 mAs was the tube current time followed by 82.4 kV tube voltage settings.

**Conclusion:** These methods can be effective in reducing radiation dose while preserving diagnostic image quality in pediatric head CT examinations.

**Keywords:** Pediatric Head CT, Radiation Dose, Tube Voltage, Tube Current Time

## INTRODUCTION

In 1970, due to excellent diagnostic accuracy, availability, short acquisition time, and cost-effectiveness the use of CT has increased rapidly which has led to various advances in modern medical practice. It has a growing concern for patient safety, as CT delivers increased doses of radiation than do most other diagnostic imaging procedures.<sup>1</sup>

Children and young adults are more sensitive to the stochastic effects of ionizing radiation due to their young bodies which undergoes rapid cell division. In addition, the relatively long remaining life span of children and young adults leaves ample time for expression of potential radiation effects compared with that of adults. It has been found from the literature that radiation-induced carcinogenesis is generally accepted as a stochastic process, whereas the probability of the occurrence of the effect increases with increasing radiation dose, but the

severity of the effect is not influenced by the dose.<sup>2</sup>

Furthermore, children receive more effective doses due to their smaller body size, if desired pediatric CT protocols are not applied. In comparison with children hospitals, it has been found that community hospitals (where most pediatric patients are likely to undergo CT) are more likely to use adult-calibrated CT protocols. Due to these reasons, there is potential increase in cancer risk among children which is a topic of concern, although considerable amount of uncertainty exists in this matter.<sup>3</sup>

The results of several studies have suggested the potential benefits of reducing radiation dose for prevention of possible future carcinogenesis attributable to CT. In a study, it was investigated that reducing the highest 25% of doses of pediatric CT to the median level might prevent 43% of future CT-induced cancers. In a similar study, it was estimated that when the dose per CT scan was reduced by 20% and 40%,

respectively, compared with past practices in the United Kingdom; the number of future cancers potentially induced at pediatric CT was reduced by 20% and 40%.<sup>4,5</sup>

Since the estimations are based on risk projection models, the actual advantage of CT dose reduction is not clear till now. However, given that results of recent epidemiologic studies on natural background and occupational protracted exposure and pediatric CT appear to be consistent with the linear non-threshold assumption, adherence to the ALARA principle is relevant and useful to save children from possible carcinogenesis caused by CT.<sup>6</sup>

There are two fundamental principles for protection from medical radiation one is justification and the other is optimization. It has been suggested from these principles that CT studies should be performed only when the clinical benefit to the patient clearly exceeds potential adverse effects of radiation exposure. Every physician and radiologist must first ensure the appropriateness of the clinical indication to avoid unnecessary scans, which is the major step for reduction in overall radiation exposure to CT.<sup>7</sup>

For the elimination of unnecessary radiation, the length of the scanning area on the body should also be limited to the area of concern. There are various techniques such as automated exposure control, lowering tube current and tube voltage, high-pitch acquisition, and IR algorithms which can help in reducing radiation dose or improving the image quality of low-dose pediatric CT.<sup>8,9</sup> Hence, the aim of the present study was to analyse the method among paediatrics to reduce radiation dose in computed tomography of brain.

### MATERIAL AND METHODS

This study was a retrospective study conducted among pediatric patients undergoing head CT examinations at radiologic centers in our institution. The examinations were performed in July 2018- June 2019. Every CT examinations were performed with one 64-MDCT scanner (center 1; Light Speed VCT, GE Healthcare).

All CT systems were equipped with patient size-based automated tube current modulation algorithms, as provided by each manufacturer (center 1, Smart mA, GE Healthcare; center 2, CARE Dose, Siemens Healthcare; center 3, Sure Exposure, Toshiba Medical Systems). A total of 100 unenhanced head CT examinations of outpatient boys and girls 1 month to 14 years old were randomly selected.

The following parameters were manually retrieved from the PACS: tube voltage, tube current, tube rotation time, acquisition mode (sequential or helical), beam pitch (for helical CT studies), detector configuration, automated tube current modulation (enabled or disabled), CT dose index (CTDI), and dose-length product (DLP). Dose-length product is an approximation of the energy absorbed by the patient. Subjective imaging quality was assessed by calculating the score obtained from the collected data from previous reports.

Based upon children age, the pediatric population was divided into three groups as: 0-4 years, 5-9 years and 10-14 years. It was ensured that the selected CT examination were free from artifacts (such as, those due to metallic hardware or external devices) severe enough to compromise diagnostic

yield. For image analysis, the examinations consisted of scout images plus a stack of 2.5-or 3-mm-thick axial images depending on the type of scanner.

### STATISTICAL ANALYSIS

The data was entered into the excel sheet and descriptive analysis was performed using statistical analysis software SPSS version 21.

### RESULTS

In the present study, out of 100 subjects, 34 and 38 subjects were scanned with the help of 350 mAs and 120 kVp and 28 were scanned with the help of 200-300 mAs. It was found that in the age group 0-4 years; tube current time was kept at 240 mAs and 57.9 kV followed by 280 mAs and 61.2 kV for 5-9 years. For the 10-14 years age group, 310 mAs was the tube current time followed by 82.4 kV tube voltage settings (Table no. 1).

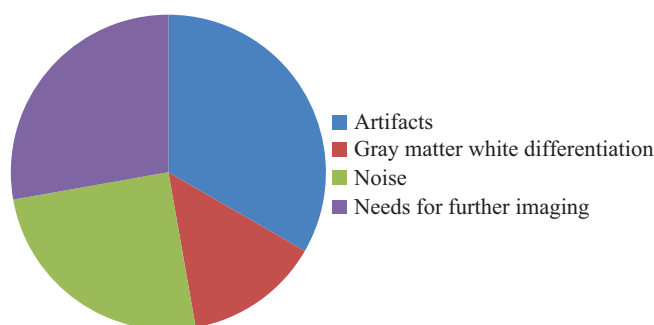
It was found that in the age group 0-4 years; gray matter conspicuity was kept at 0.24 and contrast to noise ratio was kept at 1.36. For the age group, 5-9 years, 0.20 was the gray matter conspicuity followed by 1.12 contrast to noise ratio. For the 10-14 years age group, 0.18 was the gray matter conspicuity followed by 1.28 contrast to noise ratio (Table no. 2).

| Age         | Number of patients | Tube current time setting (mAs) | Tube voltage settings (120 kV) |
|-------------|--------------------|---------------------------------|--------------------------------|
| 0-4 years   | 34                 | 240                             | 57.9                           |
| 5-9 years   | 38                 | 280                             | 61.2                           |
| 10-14 years | 28                 | 310                             | 82.4                           |

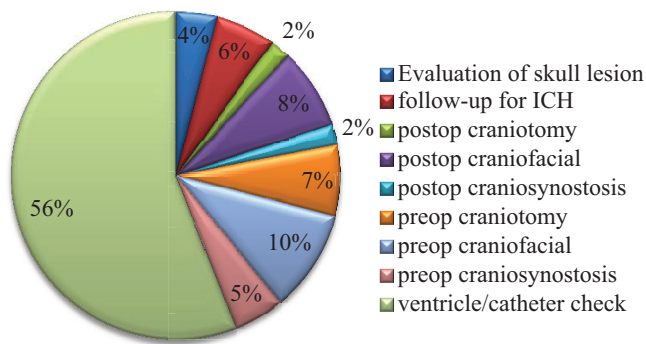
**Table-1:** Shows the distribution of data based on tube current time and tube voltage among the children of different age groups

| Age         | Number of patients | Gray Matter Conspicuity | Contrast-to-Noise Ratio |
|-------------|--------------------|-------------------------|-------------------------|
| 0-4 years   | 34                 | 0.24                    | 1.36                    |
| 5-9 years   | 38                 | 0.20                    | 1.12                    |
| 10-14 years | 28                 | 0.18                    | 1.28                    |

**Table-2:** Shows the distribution of data based on Gray Matter Conspicuity and Contrast-to-Noise Ratio among the children of different age groups



**Graph-1:** Shows the distribution of data based on subjective image quality



**Graph-2:** Shows the distribution of data based on indications and quantification of the various pathologies for low-dose head CT scans

In the present study, artifacts were found to be 24% followed by 10% gray matter white differentiation, 18% noise and 20% there was need for further imaging (Graph no. 1).

Evaluation of skull lesion was seen in 4 cases, follow-up for ICH in 6%, post-op craniotomy in 2%, postop craniofacial in 8%, postop craniostylosis among 2%, preop craniotomy in 7%, preop craniofacial in 10%, followed by 5% in preop craniostylosis and 56% in ventricle/catheter check (Graph no.2).

## DISCUSSION

Based on approved criteria or guidelines, the first is the limiting pediatric CT requests to only reasonable indications and the other strategy is to adjust technical parameters on CT scanners to lower radiation dose while retaining diagnostic image quality. This above mentioned reduction in radiation dose was linked to a significant reduction in tube voltage and the tube current- rotation time settings used for CT examinations.<sup>10</sup>

It has been observed from the previous literature that lowered settings of tube voltage cuts radiation dose more powerfully than decreasing the tube current-time settings alone, due to absorbed dose varies by approximately the square of tube voltage and only linearly with tube current. Therefore, a reduction from 140 kV to 120 kV leads to a dose reduction of approximately 30%, and a further 30% dose reduction can be achieved by switching from 120 to 100 kV.<sup>11,12</sup>

When photoelectric effect at lower x-ray energies was used, it helped in lowering the tube voltage settings which increased the contrast resolution owing to the higher attenuation of lower-energy x-rays produced by lower tube voltage and x-ray absorption. The latter effect is more pronounced with high-atomic-number objects, such as iodine from iodinated contrast material in CT angiographic studies. This increased x-ray attenuation, however, may yield overall more tissue contrast than achieved with increased tube voltage settings, potentially improving image quality along with reduced radiation dose.<sup>13,14</sup>

In the case of unenhanced CT examinations, where identification of subtle differences in tissue attenuation may be hampered by excessively high noise levels, especially in both visual and quantitative analysis of image quality revealed greater noise in target brain areas, the use of lower tube voltage and tube current-time settings has the drawback

of more image noise, which must be taken into account.

In addition, radiation dose levels in CT studies often exceed those required for diagnosis, and our finding of comparable or even higher gray matter conspicuity may be partially due to the higher intrinsic tissue contrast related to the more frequent use of lower tube voltage settings, which should partly offset the increased noise.<sup>15</sup>

The survey analysis of all of the pediatric neurosurgeons and craniofacial plastic surgeons at Seattle Children's Hospital, as well as 3 pediatric neuroradiologists, revealed that multidisciplinary support of the quality and utility of the low-dose CT scans in our selected population. These findings are in agreement with previously published smaller series that objectively demonstrated acceptable image quality, albeit with increased noise, with approximately 50% reduction in tube current. It has been a major concern in implementation of the low-dose head CT protocol which was found to be the potential for unrecognized pathology (such as hemorrhage) in the setting of reduced image quality.<sup>16,17,18</sup>

It is important to remind lastly even though a lower dose is available, low-dose CT scans still exposes each child to ionizing radiation and thus one should not expand the criteria for ordering a head CT scan. Current imaging indications must also be constantly reviewed and re-reviewed to ensure the low-dose scans are also very important. Hence, the best way to decrease the diagnostic radiation is to critically reassess the clinical utility of all radiation studies and potentially exclude imaging in children with specific indications.<sup>19,20</sup>

## CONCLUSION

It was found that for unenhanced head CT examinations, the radiation dose delivered to children varied greatly. With the continuing evolution of MDCT technology and dose-saving tools, the reduction in radiation dose can be helpful in decreasing the risk associated with the CT.

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