Research Article / Araştırma Makalesi

The Effect of Scan Length on Effective Dose in Emergency Brain CT Scans in Pediatric Patients

Çocuk Hastalarda Acil Beyin BT Çekimlerinde Tarama Uzunluğunun Etkin Doza Etkisi

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Abstract: The most significant source of human-made radiation is the radiation generated by techniques used in medicine nowadays. This study aimed to investigate the necessity of repetition of brain CT scans due to trauma in pediatric patients aged 0-6 in the emergency department, evaluate the adequacy of scan lengths, and assess the effect of the presence of a hand in the field of view on effective dose. Fifty-nine patients were evaluated in the study. Patients who underwent scanning beyond the vertex-C2 interval were recorded to have excessive scan length. Secondly, the presence of another person's limb (such as a hand) in the field of view to keep the patients for CT was recorded. Four groups were formed according to these parameters: group 1 (appropriate scan length, no hand), group 2 (appropriate scan length, hand present), group 3 (excessive scan length, no hand), group 4 (excessive scan length, hand present). The rate of images with non-diagnostic quality was determined to be 13.56%, and 54.34% had scan lengths longer than optimal. There was a statistically significant difference between groups in terms of ED1 and ED2 ($p=0.033$, $p<0.001$, respectively). Mean dose values were found to be higher compared to the literature. The analysis of ED values showed that excessive scan length increased the ED, whereas presence of a hand in the field of view did not show a significant difference. In conclusion, the study demonstrates that dose optimization in children is not optimally achieved in our hospital. These findings emphasize the importance of controlling radiation dose in this sensitive patient group.
Keywords: Brain CT, Child, Radiation dose, Imaging repetition, Dose optimization.

Özet: Günümüzde insan kaynaklı radyasyon kaynakların en önemlisi tıpta kullanılan tekniklerin ürettiği radyasyondur. Bu çalışmada acil serviste travma nedeniyle beyin BT çekimi gerçekleştirilen 0-6 yaş aralığındaki çocuk hastaların tetkilerinde çekim tekrarı gerekliliğinin araştırılması; tarama uzunluklarının uygunluğu, görüntü alanında el varlığının etkin doza etkisinin değerlendirilmesi amaçlanmıştır. Çalışmada 59 hasta değerlendirilmiştir. Vertex-C2 aralığından daha fazla tarama gerçekleştirilen hastalar tarama uzunluğu fazla olarak kaydedildi. İkinci olarak hastaların BT'de durması için görüntü aralığında başka bir insanın uzvunun (el vb.) girip girmediği kaydedildi. Bu parametrelere göre dört grup oluşturuldu; grup 1 (tarama uzunluğu uygun, el yok), grup 2 (tarama uzunluğu uygun, el var), grup 3 (tarama uzunluğu fazla, el yok), grup 4 (tarama uzunluğu fazla, el var). Tanısal kalitede olmayan görüntülerin oranı %13,56 olarak belirlenmiş, %54,34'ünde ise tarama uzunluğu optimalden fazla bulunmuştur. Gruplar arasında ED1 ve ED2 arasında istastistiksel olarak anlamlı fark vardı ($p=0,033$, $p<0,001$, sırasıyla). Ortalama doz değerleri literatürle karşılaştırıldığında yüksek bulunmuştur. Hastaların gruplara ayrılması ve ED değerlerinin analizi, fazla tarama uzunluğunun ED'yi artırdığını, görüntüye el girmesinin ise anlamlı fark göstermediğini ortaya koymuştur. Sonuç olarak, çalışma, çocuklarda doz optimizasyonun hastanemizde optimal sağlanamadığını göstermektedir. Bu bulgular, radyasyona duyarlı bu hasta grubunda radyasyon dozunun kontrol altında tutulmasının önemini vurgulamaktadır.
Anahtar Kelimeler: Beyin BT, Çocuk, Radyasyon, Tetkik tekrarı, Doz optimizasyonu

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1. Introduction

There can be mentioned many effects of ionizing radiation on tissue and organ systems. However, these effects can be primarily categorized into two groups: stochastic effects and deterministic effects. Deterministic effects are the effects that occur due to excessive cell death secondary to radiation exposure. For these effects to occur, a certain threshold value must be exceeded. Examples of deterministic effects include acute radiation syndrome, erythema on the skin, tissue necrosis, cataracts, and suppression of bone marrow (1). On the other hand, no specific threshold value can be mentioned for the occurrence of stochastic effects. These effects emerge after a latent period following radiation exposure. Although the probability of these effects occurring increases with dose, there is no relationship between the severity or seriousness of the findings and the dose. Stochastic effects can be considered as cancer development and mutagenic-teratogenic effects (2).

The most significant source of human-made radiation is generated by medical techniques, notably computed tomography (CT), interventional radiological procedures, and nuclear medicine procedures nowadays (3). Our country is one of the most frequently using countries for diagnostic radiation sources (4). For these reasons, reducing society's exposure to radiation is crucial. Reducing unnecessary radiation exposure can be categorized into two main areas. The first is reducing unnecessary medical requests to eliminate patients' radiation exposure. Secondly, obtaining diagnostic quality images with the least possible radiation for patients requiring imaging is essential. Therefore, some measures to reduce dose include reducing repeat imaging, adjusting parameters such as pitch settings, tube potential, optimizing automatic tube current modulation, adjusting the scanning interval appropriately, and giving the patient an appropriate position (5). Considering the effect of radiation, children are more sensitive to radiation. Additionally, the possibility of movement during imaging and differences in body proportions compared to adults can lead to increased radiation exposure (6). In our country, there is a lack of comprehensive data on the frequency and necessity of these imaging techniques, particularly in pediatric patients. Previous research has often overlooked the specific needs and vulnerabilities of children when it comes to radiation exposure. Moreover, there is a noticeable gap in national data and guidelines tailored to reduce unnecessary radiation exposure in pediatric imaging.

This study aimed to investigate the necessity of imaging repetition in brain CT scans performed on pediatric patients aged 0-6 years in the emergency department due to trauma. The appropriateness of scanning lengths and the effect of hand presence in the imaging field on effective dose were evaluated.

2. Materials and Methods

Prior to the study, approval was obtained from the Ethics Committee for Non-Interventional Clinical Research at Eskisehir University (Decision No: 33 Date: 27.02.2024).

Patients aged 0-6 years who underwent non-contrast brain CT examinations due to trauma were included in the study, conducted in the emergency department or pediatric emergency department of our hospital between October 1, 2023, and January 1, 2024. Children who were not within the specified age range, those who underwent imaging for reasons other than trauma during this period, and those for whom the DLP (Dose-Length Product) value could not be obtained were excluded from the study. All scans were performed on a 128-slice CT scanner (GE Optima).

Gender and age information of the patients were recorded. The images were re-evaluated by two radiologists with two and eight years of experience in radiology, respectively. Decisions were made through discussion and consensus. Brain CT images were assessed for diagnostic quality. Examinations that were not diagnostically optimal due to motion or artifacts were recorded as "image repetition required."

Patients were divided into four groups based on two criteria. Firstly, the starting (vertex, etc.) and ending levels (C2-T1) of brain CT slices were recorded. Patients who had more scans beyond this range, as assessed by evaluating the optimal scanning interval from vertex to C2, were recorded as having excessive scan lengths. Secondly, the presence of another person's limb (e.g., hand) in the imaging field to keep patients still during CT was noted. Based on these parameters, four groups were created: group 1 (appropriate scan length, no hand presence), group 2 (appropriate scan length, hand presence), group 3 (excessive scan length, no hand presence), and group 4 (excessive scan length, hand presence).

Patients' DLP values were recorded. Effective dose (ED) calculation was performed using an internet-based calculation tool. Internet-based calculation tools are user-friendly applications that provide dose estimations by allowing users to input specific parameters such as age, body region, and DLP values. There are many internet-based dose calculation sites, some of which use different methods. In this study calculations were performed from a frequently used website (7). In this calculation application, parameters of 0 years for the 0-11 months group, 1 year for the 11-23 months group, and 5 years for the 24-71 months group were selected. Additionally, the body region was set as "head" for ED calculation. This calculation was referred to as ED1. Furthermore, due to the potential increase in ED caused by excessive scan length in groups 3 and 4, as if performing a neck CT examination, a second calculation was performed selecting the body region as "head and neck" for these two groups. For groups 1 and 2, ED1 values were reused. These values were referred to as ED2.

2.1. Statistics

The normal distribution of the data was assessed using the Kolmogorow-Smirnov test. Non-parametric data were expressed as median (IQR). The relationship between ED values among the four groups was evaluated using the Kruskal Wallis H-Test. The comparison between each group was analyzed using the Mann-Whitney U test. A p-value <0.05 was considered statistically significant.

3. Results

A total of 59 patients who met the inclusion criteria during the study period were included. Of these patients, 20 were female and 39 were male. The average age was 23.5 (26) months for females, 42 (55) months for males, and 28 (55) months overall. Diagnostic quality was considered suboptimal and in need of repetition in 8 patients. The scan length was above normal in 32 patients, and the presence of hand was detected in the image field in 23 patients (Table 1).

Table 1. Distribution of patients according to scan length

Scan length	
Vertex-C2	27 (45.76%)
Vertex-C3	2 (3.39%)
Vertex-C4	14 (23.73%)
Vertex-C5	6 (10.17%)
Vertex-C6	1 (1.69%)
Vertex-C7	1 (1.69%)
Vertex-T1	4 (6.78%)
Vertex-T2	3 (5.08%)
Vertex-T3	1 (1.69%)

DLP was calculated as 839.24 (409.62) mGy-cm, ED1 as 4.164 (2.463) mSv, and ED2 as 5.3 (3.612) mSv. When evaluated with the Kruskal Wallis H test among groups, there were statistically significant differences in age, ED1, and ED2 (p=0.007, p=0.033, p<0.001, respectively) (Table 2)(Figure). When the study group was evaluated in the age ranges of 0-1 year and 1-5 years, ED1 was calculated as 5.381 (3.864) mSv and 3.984 (1.36) mSv, respectively; ED2 was calculated as 5.381 (4.685) mSv and 5.05 (3.2) mSv, respectively.

Table 2. Age and effective dose comparison of patients by groups

	Group 1 (n=17)	**Group 2 (n=10)**	**Group 3 (n=19)**	**Group 4 (n=13)**	**p-values**
Age (month)	67 (46)	18.5 (12)	47 (54)	25 (17)	0.007
Effective Dose 1 (mSv)	3.356 (1.218)	4.487 (2.707)	4.328 (1.472)	4.716 (2.458)	0.033
Effective Dose 2 (mSv)	3.356 (1.218)	4.487 (2.707)	6.167 (2.758)	6.72 (2.434)	<0.001

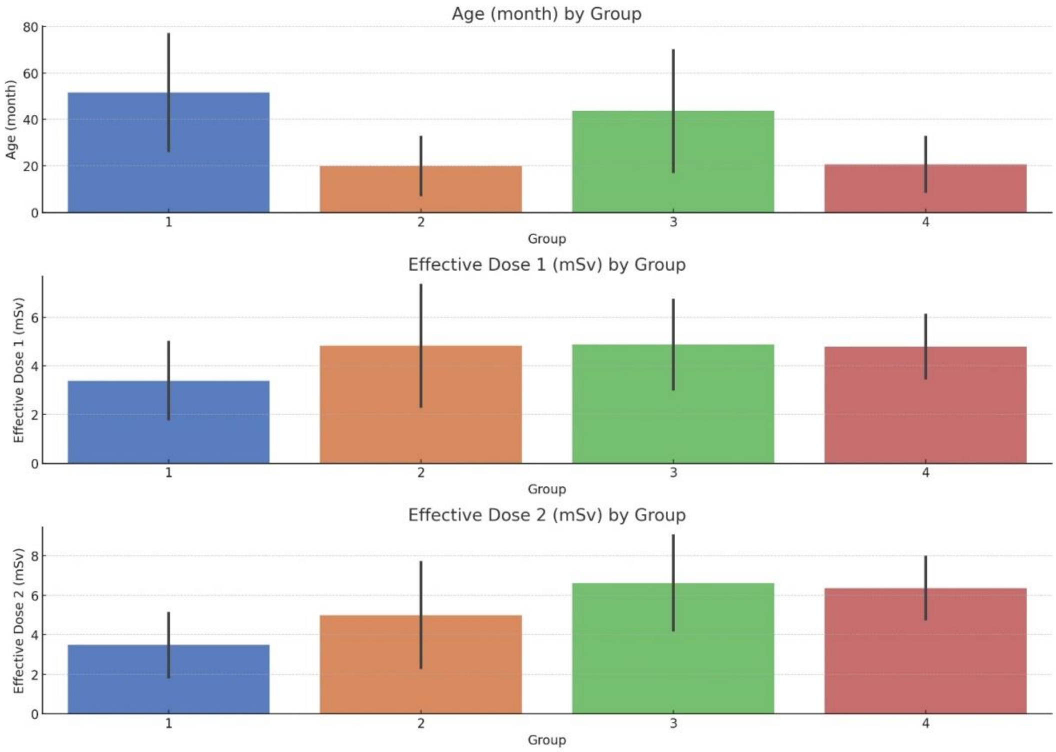

Figure. The bar graphs display the average age (months) and Effective Dose (ED1 and ED2 in mSv) for each group, with standard deviation error bars indicating variability within each group.

ED1 and ED2 values were individually evaluated pairwise among each group. In both values, patients in Group 1, where the scans were optimally performed, had statistically lower doses compared to patients in Group 3 and Group 4. In the ED2 dataset, patients in Group 1 had statistically lower doses compared to patients in Group 3 and Group 4, and patients in Group 2 had statistically lower doses compared to patients in Group 3. The findings are summarized in Table 3.

Table 3. Comparison of patient groups in terms of effective dose

Effective Dose 1	Group 2 (n=10)	Group 3 (n=19)	Group 4 (n=13)
Group 1	0.209	**0.006**	**0.014**
Group 2		0.582	0.577
Group 3			0.803
Effective Dose 2			
Group 1	0.248	**<0.001**	**<0.001**
Group 2		**0.048**	0.072
Group 3			0.954

4. Discussion and Conclusion

Head trauma constitutes the most common indication for brain CT in the pediatric patient population. Considering that traumatic brain injury is a leading cause of morbidity and mortality in pediatric patients, this indication is understandable (8,9). However, despite this, many patients presenting with head trauma have only moderate traumatic brain injury. This underscores the importance of judiciously requesting brain CT scans in children within the indication. Therefore, recommendations have been made in the literature to reduce the rates of brain CT requests (10). Apart from inappropriate requests, reducing the number of repeat scans and adhering to anatomical imaging distances are also necessary to reduce radiation doses in the pediatric population (11). It should be noted that children are more sensitive to radiation. In a review, it was stated that for every 4000 brain CT scans in children (40 mSv per scan), one brain malignancy occurs, and exposure to 10 mGy before the age of 10 increases the estimated risk to 1 brain tumor per 10,000 patients within the following 10 years (12).

In this study, the ED1 was calculated as 4.164 (2.463) mSv, and ED2 was calculated as 5.3 (3.612) mSv. In studies conducted in the pediatric population, different values of ED have been reported. However, studies have indicated that ED is higher in the 0-1 age group compared to other age groups (13). In the literature, dose values in the range of 1.7-5.1 mSv have been reported for the 0-1 age group, while for the 1-5 age group, values in the range of 1.2-3.17 have been reported (14,15). The values in this study were higher in the 0-1 age group, which is consistent with the literature. However, when evaluated for both age groups compared to the literature, the ED was relatively higher. This could be attributed to the excessive scan length in 54.34% of the study population.

The frequency of repeated CT scans due to re-requested examinations varies in the literature. These situations can occur before the patient is referred to another hospital or after they are referred to the receiving hospital. Additionally, it is known that CT scans are repeated in trauma patients when they are referred to trauma centers. In these studies, the effect of repeated scans on the adverse effects of radiation has been investigated (17,18). The terms "repeat" and "reject" are used to distinguish between repeated scans and those rejected due to inadequate diagnostic quality. However, there are not many studies in the literature specifically addressing the repetition of scans rejected due to inadequate diagnostic quality. In one study, this rate was reported as 1.2% (19). In the mentioned study, the entire patient population in all age groups was included. Additionally, in the same study, patients' hospitals were categorized as rural and academic environments, and it was stated that scan repetition rates were higher in rural areas (19). In another study, the impact of CT optimization training was investigated, and it was reported that the reject rates decreased from 13% before training to 0% after training (20). The high rate observed in this study may be attributed to the pediatric nature of the patients and the agitation of pediatric patients due to trauma.

The patient population was divided into 4 groups in this study. When these groups were evaluated, a significant finding emerged regarding the effect of scan length on effective dose (ED) for both "head" (ED1) and "head and neck" (ED2) scans. There are studies in the literature indicating that approximately 95% of patients are not properly positioned on the gantry by technicians during CT scans (5). Additionally, the scanned area should be within standard anatomical reference points. There is a linear relationship between the distance in the cranio-caudal plane to be scanned and the ED (5). It is known that longer than expected scan lengths or improper positioning of the patient on the CT gantry can lead to a significant increase in surface dose to the patient (21). In a study conducted on pediatric patients with suspected acute appendicitis, scanning the length between the superior corpus of L2 vertebra and superior pubic symphysis resulted in approximately 46% reduction in ED (22). Another finding of this study is that holding children to prevent movement does not have a significant effect on ED. In this regard, no significant difference was found between Group 1 and Group 2, as well as between Group 3 and Group 4.

The findings from this study have significant clinical implications and offer concrete recommendations for future research. It is suggested that further studies be conducted for each age group to gather more detailed data on radiation exposure in pediatric patients. Multi-center studies comparing different hospitals, including rural and urban settings, would provide a broader perspective on the issue. Furthermore, implementing standardized imaging protocols and continuous training programs for radiology technicians could lead to significant reductions in unnecessary radiation exposure.

This study has some limitations. First, the study was conducted retrospectively, and the size of the study population is relatively small. Prospective studies with larger patient populations could contribute to this field. Second, although a calculation tool including an accepted ED calculation technique was used, ED doses may not fully reflect reality. Therefore, in patients with excessive scan lengths, "head and neck" ED calculation was additionally used. We believe that ED1 and ED2 calculations will provide an idea to reduce this limitation. Finally, especially in patients with manual interference in the image (Group 2, Group 4), the average age was lower compared to other groups. This may have caused differences in ED calculations.

In conclusion, we evaluated brain CT scans in the 0-6 age group obtained from emergency services. When evaluated with the literature, it was determined that patients' images not being diagnostically adequate (13.56%) and having longer scan lengths than optimal (54.34%) were important factors increasing patient dose. The ED received by the study population was relatively high compared to the literature. Especially in this patient population, which is more sensitive to radiation and has a longer life expectancy, it should be kept in mind that as the radiation dose increases, the incidence of cancer may increase. In this context, especially in our country where a large number of radiological requests are made, it is important for each hospital to establish, monitor, and train radiology technicians on imaging protocols.

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Ethics

Ethics Committee Approval: The study was approved by Eskişehir Osmangazi University Noninterventional Clinical Research Ethical Committee (Decision no: 33, Date: 27. 02.2024).

Informed Consent: The authors declared that it was not considered necessary to get consent from the patients because the study was a retrospective data analysis.

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