Research Article (Araştırma Makalesi)

Evaluation of Radiation Exposure in Pediatric Cranial Trauma Patients

Çocuk Kraniyal Travma Hastalarında Radyasyon Maruziyetinin Değerlendirilmesi

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Özet

Amaç: Bu çalışmanın amacı, acil servislere minör kafa travması ile başvuran çocuklarda kraniyal bilgisayarlı tomografi (BT) taramalarının radyasyon maruziyetini değerlendirmektir.

Gereç ve Yöntemler: Minör kafa travması nedeniyle acil serviste BT çekilen 1199 hastanın radyasyon dozu hesap edilmiştir.

Bulgular: Beyin BT çekilen 0-5 yaş arası çocuklarda 5-16 yaş arası çocuklara göre anlamlı olarak daha yüksek dozda radyasyona maruz kaldıklarını tespit ettik (p<0.001). Servikal BT ve abdominal BT çekilen çocuk hastalarda yaş gruplarına göre radyasyon maruziyetleri arasında anlamlı bir fark yoktu (sırasıyla p=0.838, p=0.106). Toraks BT çekilen çocuk hastalarda 10-16 yaş arası çocuklarda 0-1 yaş arası çocuklara göre anlamlı olarak daha yüksek dozda radyasyona maruz kaldıkları tespit edildi (p=0.001).

Sonuç: Acil servise kafa travması ile gelen çocuklarda kraniyal BT kullanımının klinik gözlem ve iyonizan radyasyonun olumsuz etkileri konusunda hasta - yakınlarının bilgilendirilmesi ile ve istem yapan doktorların eğitimi ile azaltılabileceğini öneriyoruz.

Anahtar kelimeler: Bilgisayarlı tomografi, Çocuklar, Kafa travması, Radyasyon dozu, Radyasyon maruziyeti

Abstract

Objective: The present study aims to evaluate radiation exposure in cranial computed tomography (CT) scans of children who were admitted to an emergency service due to minor cranial trauma.

Materials and Methods: Radiation exposure doses of 1199 patients with CT scans due to minor cranial trauma in an emergency service were calculated.

Results: It was found that children aged 0 to 5 were exposed to a significantly higher radiation dose compared to those aged 5 to 16. (p<0.001). However, no significant differences were observed among children with cervical and abdominal CT scans in terms of their age groups (p=0.838 and p=0.106, respectively). Finally, it was observed that among children with thorax CT scans, those aged 10 to 16 were exposed to a significantly higher radiation dose compared to those aged 0 to 1. (p=0.001).

Conclusion: We suggest that the use of cranial CT scan in children admitted to an emergency service due to cranial trauma can be reduced by clinical monitoring, informing the patient and parents about negative effects of ionizing radiation and training physicians about CT scan orders.

Keywords: Computed tomography, Children, Cranial trauma, Radiation dose, Radiation exposure

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INTRODUCTION

Every year, 185 in 100.000 people are admitted to an emergency service due to minor cranial trauma. Cranial traumas are one of the leading causes of morbidity and mortality among children age groups (1,2). Since Computed Tomography (CT) takes a relatively short time and is a reliable diagnosis method, it is frequently used in emergency services in the diagnosis of patients suffering from cranial traumas (3,4). Given that children are more sensitive to radiation compared to adults, such medical practices are likely to result in serious health problems (4,5). One of the most visible effects of radiation exposure is that it contributes to the likelihood of cancer development. It was reported that radiation exposure at an early age may increase risk of cancer at a higher level when compared to adulthood (6).

Cranial CT is a widely used imaging method for cranial traumas. However, the use of CT scans in pediatric cranial traumas have been controversial until today.

As the rate of negative CT scans varies between 83% and 97% in minor cranial traumas, the rate of patients with positive CT scan diagnosis which requires brain surgery is less than 1% (6, 7). It is understood from the literature that there is unnecessary ionizing radiation exposure. The main objective of the present study is to evaluate radiation exposure doses in pediatric cranial CT scans for minor cranial traumas in an emergency service and thus contribute to CT scan order criteria.

MATERIALS AND METHODS

The present study was approved by the local ethical committee in session 29/08/2018 with the protocol number 07. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Study Design

1199 patients who were admitted to our pediatric emergency service due to minor cranial trauma and underwent cranial CT scan in accordance with PECARN criteria between January 2018 and January 2019 were included in the present study. The average age of the patients was 6.87±4.57 (0.08-16). 408 (34%) patients were female, while 791 (66%) of them were male. All 1199 patients underwent cranial CT scan. In addition, the number of patients with a cervical CT, thorax CT or an abdominal CT scan was 335, 209 and 176, respectively.

Each patient's radiation dose value was calculated for each CT scan. The formula DLP x k = mSv was used for radiation exposure calculation (8). Because k value in this equation differed among different anatomical regions and age groups (**Table 1**) (8), the patients were divided into four different groups: Group A (aged 0 to 1), Group B (aged 1 to 5), Group C (aged 5 to 10) and Group D (aged 10 to 16).

Brain CT was applied using a 16-dedector-array CT device (Alexion, Toshiba MedicalSystems, Nasu, Japan) with a tube voltage of 80 to 120 kVp and a current of 200 mAs. The slice thickness was 3 mm, reconstruction increment was 1.5 mm, and volume CT dose index was 53.10–68.50 mGy.

CT scan symptoms of the patients were classified as follows:

1. No radiological symptoms
2. Cranial injury
3. Extremity fracture
4. Abdominal solid organ injury
5. Thoracic injury
6. Spinal injury

Cranial injury symptoms in the list above were divided into seven different sub-categories as follows:

Table 1. Changing k values in radiation dose calculation for different age groups and regions of the body

Region of Body	k ($mSv\ mGy^{-1}\ cm^{-1}$)				
	0 year old	**1 year old**	**5 year old**	**10 year old**	**Adult**
Head and neck	0.013	0.0085	0.0057	0.0042	0.0031
Head	0.011	0.0067	0.0040	0.0032	0.0021
Neck	0.017	0.012	0.011	0.0079	0.0059
Chest	0.039	0.026	0.018	0.013	0.014
Abdomen-pelvis	0.049	0.030	0.020	0.015	0.015
Trunk	0.044	0.028	0.019	0.014	0.015

2;1-Contusion
2;2-Subdural hematoma
2;3-Epidural hematoma
2;4-Subarachnoid hemorrhage
2;5-Skull fracture
2;6-Soft tissue trauma
2;7-Multiple injury

Soft tissue trauma was included in a separate sub-category (2;6) on its own. It was included in skull fracture sub-category (2;5) if skull fracture was present without any intracranial symptoms, regardless of the presence of soft tissue components. When only a single intracranial symptom, i.e. contusion, subdural hematoma, epidural hematoma and subarachnoid hemorrhage, was present, each of them was included in its own sub-category. However, it was included in multiple injury sub-category (2;7) in the presence of two or more intracranial symptoms.

Excluse Criteria

Apart from patients with CT scans due to minor cranial trauma, the patients who underwent a CT scan due to another trauma or other reasons were not included in the present study. In addition, patients aged over 16 were also excluded.

Statistical Analysis

Statistical studies were conducted using Statistical Package for the Social Sciences for Windows (SPSS Inc, Chicago) 22 package program. Variables were expressed as mean ± standard deviation, number (n), and percentage (%). Kolmogorov-Smirnov test was used to evaluate whether numerical variables were normally distributed. A Chi-square test was used to compare categorical variables. Student's t-test or one-way analysis of variance (ANOVA) was used for normally distributed parameters. Mann Whitney U-test or Kruskal Wallis test was used for non-normally distributed parameters. When significant differences were observed between more than two groups according to post hoc analysis using Scheffe's method to determine the differences between the groups.

The present study was approved by the Kahramanmaraş Sütçü İmam University, Medical Research, local ethical committee in session 29/08/2018 with the protocol number 07.

RESULTS

Following the exclusion criteria, the number of patients who were admitted to our emergency service due to minor cranial trauma and underwent cranial CT scan in accordance with PECARN criteria was 1199, and their ratio to all patients with minor cranial trauma was 28.9%. The patients without any cranial CT scans were discharged after a direct radiographic evaluation and monitoring.

The distribution of the patients in different age groups (Table 2): There were 150 patients (12.5%) in Group A (aged 0 to 1), 351 patients (29.3%) in Group B (aged 1 to 5), 347 patients (28.9%) in Group C (aged 5 to 10), and 351 patients (29.3%) in Group D (aged 10 to 16).

The distribution of the patients' CT scan symptoms in different age groups (Table 3): When the patients' pathological radiology symptoms are analyzed in terms of their age groups, it can be observed that the rate of absence of pathological symptoms (915 patients, 76.3%) was significantly higher in all age groups (p=0.019). Cranial injury was the most frequent form of cranial traumas.

The distribution of the cranial trauma symptoms in CT scans in all age groups (Table 4): When the patients' cranial traumas were analyzed in terms of their age groups, no significant differences were found among their age groups in terms of their types of cranial trauma (p=0.069). However, the most frequent cranial trauma diagnoses were soft tissue trauma and skull fracture. The age group with the most frequent rate of cranial trauma was 5 to 10.

The patients' radiation exposure rates in terms of their age groups and CT scan regions (Table 5): It was demonstrated in the present study that children with cranial CT scan aged between 5 and 10 were exposed to a higher radiation dose compared to those aged between

Table 2. The distribution of the patients in different age groups

Group	A	B	C	D
Age group (years)	0-1	1-5	5-10	10-16
Number of patients	150	351	347	351
%	12.5	29.3	28.9	29.3

Table 3. The distribution of the patients' CT scan symptoms in different age groups

Pathological symptom	(N-%)	Age Groups				
		A (N-%)	B (N-%)	C (N-%)	D (N-%)	p
No findings	(915) (76.3)	118-78.7	285-81.2	246-70.9	269-76.6	0.019
Cranial injury	(235) (19.5)	30-20	58-16.6	88-25.4	269-76.6	
Extremity fracture	(27) (2.2)	2-1.3	5-1.4	9-2.6	11-3.2	
Solid organ injury	(11) (0.9)	0-0	1-0.3	3-0.9	7-2	
Thorax injury	(5) (0.4)	0-0	2-0.6	0-0	3-0.9	
Spinal injury	(3) (0.2)	0-0	0-0	1-0.3	2-0.6	

Statistics: Crosstab, chi-square test

Abbreviations: CT: Computed tomography

Table 4. The distribution of the cranial trauma symptoms in CT scans in all age groups

Cranial Injury	(N-%)	Age Groups				
		A (N-%)	B (N-%)	C (N-%)	D (N-%)	p
Contusion	(6) (0.2)	0-0	0-0	4-4.5	2-3.4	0.069
Subdural hematoma	(2) (0.8)	1-3.4	0-0	0-0	1-1.7	
Epidural hematoma	(2) (0.8)	0-0	0-0	1-1.1	1-1.7	
Subarachnoid hemorrhage	(0) (0)	0-0	0-0	0-0	0-0	
Skull fracture	(57) (24.2)	10-34.5	17-29.3	13-14.8	17-28.8	
STT	(137) (58.2)	12-41.4	34-58.6	63-71.6	28-47.5	
Multiple injury	(30) (12.7)	6-20.7	7-12.1	7-8	10-16.9	

Statistics: Crosstab, chi-square test

Abbreviations: STT: Soft tissue trauma

Table 5. The patients' radiation exposure rates in terms of their age groups and CT scan regions

CT scan region	(N-%)	Age groups				
		A Mean±SD	B Mean±SD	C Mean±SD	D Mean±SD	p
Cranial	(1199) (100)	4.07±0.95	3.85±1.04	3.22±1.18	3.12±1.45	<0.001
Cervical	(335) (27.9)	0.45±0.29	0.44±0.44	0.42±0.26	0.41±0.16	0.838
Thorax	(209) (17.4)	1.47±0.78	1.72±0.84	1.78±0.61	2.12±0.80	0.001
Abdominal	(176) (14.6)	2.19±1.03	3.47±1.82	3.74±1.01	3.55±1.28	0.106

Statistics: One Way ANOVA, Post Hoc Tests

Abbreviations: CT: Computed tomography

SD: Standard deviation

5 and 16 (p<0.001). On the other hand, there were no significant differences among radiation exposure doses in children with cervical and abdominal CT scans in terms of their age groups (p=0.838 and p=0.106, respectively). Finally, it was observed that children with thorax CT scan aged between 10 and 16 were exposed to a higher radiation dose compared to those aged between 0 and 1 (p=0.001).

DISCUSSION

One of the most common imaging techniques for pediatric cranial trauma patients in an emergency service is CT (9). However, no symptoms are found in relation to minor cranial trauma as far as 83% to 97% of these CT scans are concerned (5, 7). Similar to the findings in the existing literature, no symptoms were observed in 76.3% of CT scans in the present study. In addition, the most frequent diagnosis in the patients with CT scan was soft tissue trauma in the present study. More than half of the patients with CT scan symptoms were outpatients, which points to an unnecessary use of CT scan and, unsurprisingly, unnecessary radiation exposure.

Radiation exposure leads to a higher risk of cancer, respiratory tract diseases, heart diseases and paralysis. The risk of cancer is attributed to a higher radiation dose, while children, women and pregnant women may face a risk of cancer even in lower doses (10, 11). There are many studies emphasizing the relationship between radiation doses and risk of cancer in the current literature. A study at University of Oxford reported that a radiation exposure dose of 10 to 20 mSv may increase risk of cancer in children aged between 0 and 15 by 40% (10- 12). In the present study, the radiation exposure dose resulting from a cranial CT scan was nearly 3 to 4 mSv.

In the light of the findings and discussion above (mostly risky CT scans with no visible symptoms), it is of vital importance to re-evaluate CT scan order criteria. There is no international consensus on the management pediatric cranial traumas. Various international hospitals and trauma centers often rely on different guidelines to manage their pediatric cranial trauma patients (13). Among these are US-based Pediatric Emergency Care Applied Research Network (PECARN), UK-based algorithm for the prediction of important clinical events in children's head injuries (CHALICE) and Canadian Assessment of Tomography for Childhood Head Injury (CATCH) (14-16). The most widely used guideline in the world is PECARN, which is also acknowledged by our emergency service unit. Nevertheless, these criteria pose some problems in terms of universality such as different patient populations, availability of different fundamental sources and a different understanding of injury mechanism and injury severity (17).

Another subjective factor which can disrupt the universality of these criteria is the parents' approach. In general, parents are asked to answer some questions regarding their child's post-trauma condition, which is particularly important in younger children. The responses to this question are among CT indication criteria. It must be still noted that parents may be overwhelmed by their emotions when their child is under medical risk. In this respect, they may assume that any non-invasive procedures may contribute to the final diagnosis positively. However, radiological procedures do not usually involve invasive content, and thus the parents may urge the physician to include radiological procedures in the medical examination process. These subjective opinions will eventually decrease the objectivity of a medical diagnosis. It was observed in some studies that cranial CT scan orders dropped by 50% when the patient's relatives were informed about ionizing radiation (18, 19). As a result, some brief information about the findings of the present study prior to a CT scan may help a child's parents take a more objective decision.

Another point which cannot be associated with universality principle is a physician's level of knowledge in an emergency service. It must be questioned to what extent physicians are informed about ionizing radiation exposure doses in a CT scan as well as its consequent effects on children. Therefore, in-service trainings focusing on this particular topic is likely to diminish a physician's subjectivity towards CT scan orders. The findings of the present study are also expected to contribute to such trainings.

Despite its visible ionizing radiation exposure rates, CT scans are still popular in routine medical practices because of its diagnostic contribution. First of all, it must be used according to predetermined criteria for medical indications. If the number of medical cases without any symptoms is still high, these predetermined criteria must be further strengthened. The present study attempted to draw attention to some subjective aspects of the above-mentioned criteria. Further studies can be conducted in order to mitigate negative CT scan rates and minimize the effects of ionizing radiation exposure.

Children admitted to an emergency service due to minor cranial trauma may not always require a CT scan order. The main decision factors here must take into account the patient's medical conditions, age, parents' consent and clinical monitoring.

Limitations of the study are; In our emergency service, the degree to which parents were asked to express their opinions on CT scan orders (according to PECARN criteria) was not scored. Another limitation of the present study is its retrospectivity. It can be suggested that future studies focus on the impact of parents' opinions for CT scan orders to gain more insight into this aspect.

We suggest that in addition to clinical monitoring in pediatric cranial trauma in an emergency service, CT scan orders must be reduced through informing parents about radiation exposure doses and its negative effects and training physicians about the necessity of a CT scan order.

Ethical Approval: The present study was approved by the Kahramanmaraş Sütçü İmam University, Clinic Research, local ethical committee in session 29/08/2018 with the protocol number 07. The study is compatible with the ethical standards of the national research committee and the 1964 Helsinki Declaration and its later amendments.

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Declaration of Competing Interest: None

Author Contribution Statement: KD designed the study and transcribed the data. AD was included in the measurements. SNK contributed to the evaluation of the measurements. HH performed the clinical correlation of the patients. SG performed the statistical analyses. All authors saw and approved the final version of the study.

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