Trends of CT Use in the Pediatric Emergency Department in a Tertiary Academic Hospital of Korea during 2001-2010

Hye Yeon Oh, MD¹, Eun Young Kim, MD¹, Jee-Eun Kim, MD¹, Yoo Jin Kim, MD¹, Hye-Young Choi, MD¹, Jinseong Cho, MD², Hyuk Jun Yang, MD², Eell Ryoo, MD³

Departments of ¹Radiology, ²Emergency Medicine and ³Pediatrics, Gachon University Gil Hospital, Incheon 405-760, Korea

Objective: We wanted to assess the trends of computed tomography (CT) examinations in a pediatric emergency department (ED).

Materials and Methods: We searched the medical database to identify the pediatric patients who had visited the ED, and the number of CTs conducted from January 2001 to December 2010. We analyzed the types of CTs, according to the anatomic region, and the patients who underwent CT examinations for multiple regions. Data were stratified, according to the patient age (< 13 years and 13 ≤ ages < 18 years).

Results: The number of CTs performed per 1000 patients increased by 92% during the 10-year period (per 1000 patients, increased from 50.1 CTs in 2001 to 156.5 CTs in 2006, and then decreased to 96.0 CTs in 2010). Although head CTs were performed most often (74.6% of all CTs), facial bone CTs showed the largest rate of increase (3188%) per 1000 patients, followed by cervical CTs (642%), abdominal CTs (474%), miscellaneous CTs (236%), chest CTs (89%) and head CTs (39%). The number of patients who had CT examinations for multiple regions in the same day showed a similar pattern of increase, to that of overall CT examinations. Increase of CT utilization was more pronounced in adolescents than in pediatric patients younger than 13 years (189% vs. 59%).

Conclusion: The utilization of CTs increases from 2001 to 2006, and has declined since 2006. The increase of CTs is more pronounced in adolescents, and facial bone CTs prevail in increased number of examination followed by cervical CTs, abdominal CTs, miscellaneous CTs, chest CTs, and head CTs.

Index terms: Computed tomography; Utilization; Pediatric; Emergency department

INTRODUCTION

Although previous studies have reported that pediatric

patients are more sensitive to radiation exposure than adult patients, several reports from Western countries showed a steady increase in computed tomography (CT) examinations for pediatric patients in the emergency department (ED) (1, 2). Since this has become a source of concern to the medical community, from the perspective of increased cost and radiation dose to pediatric patients, detailed analysis of CT utilization pattern in the pediatric ED would be valuable. The purpose of this study is to assess the trends of CT examinations in a pediatric ED of Korea.

MATERIALS AND METHODS

The institutional review board of our hospital approved

Received March 7, 2012; accepted after revision May 2, 2012.
This study was supported by a grant from Gachon University Gil Hospital Research fund.

Corresponding author: Eun Young Kim, MD, Department of Radiology, Gachon University Gil Hospital, 1198 Guwol-dong, Namdong-gu, Incheon 405-760, Korea.

• Tel: (8232) 460-3060 • Fax: (8232) 460-3065
• E-mail: oneshot0229@gmail.com

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

this retrospective study and the requirement for informed patient consent was waived.

Study Population

We searched the Gachon University Gil Hospital Emergency Center Database (GUGHEC database) to identify all patients (< 18 years) in the pediatric ED between January 2001 and December 2010. Using the radiology database, we identified CT scans performed on the pediatric ED. CT scan data were also stratified according to the patient age into two groups: < 13 years of age and adolescents ($13 \leq \text{ages} < 18$ years).

CT Scans

In our hospital, a multi-detector CT (MDCT) (Somatom Sensation 16 scanner, Siemens Medical Solutions, Forchheim, Germany) has been exclusively used for ED patients, since March 2005. Before March 2005, a single-spiral CT (Somatom Plus Four Expert, Siemens Medical Solutions, Forchheim, Germany) was used for patients in the pediatric ED.

CT scans were categorized according to the regions of the body into six groups: head, facial bone, cervical, chest, abdomen and miscellaneous. Facial bone CTs included the facial bone, orbit, mandible and paranasal sinus. Abdominal CTs included only abdomen CTs, as well as abdomen and pelvic CTs. Miscellaneous CTs contained various uncommon CT scans (CTs of the thoracic or lumbar spine and extremities, and various CT angiographies).

Methods of Measurement

We assessed the total number of patients who visited the pediatric ED and the number of CT examinations for patients, and calculated the number of CT examinations per 1000 patients. Increased rates of CT scans, as classified according to the body parts, were also calculated as follows.

Increased rate of CT scans from 2001.

$$= (\text{Number of CTs per 1000 patients in the year} - \text{number of CTs per 1000 patients in 2001}) / \text{number of CTs per 1000}$$

patients in 2001.

Using the GUGHEC and radiology database, we also assessed the number of patients who underwent CT examinations for multiple regions in the same day in the pediatric ED, in addition to the body part and reasons for the examinations.

Statistical Analysis

Standard descriptive statistical methods were performed using Microsoft Excel 2007 (Microsoft, Redmond, WA, USA).

RESULTS

A total of 193444 pediatric patients (113916 boys and 79528 girls, the mean age: 5 years, the number of pediatric patients younger than 13 years of age and adolescents was 169689 and 23755, respectively) visited our ED and a total of 20450 CT examinations were conducted on 18346 pediatric ED patients (12261 boys and 6085 girls, mean age: 6 years). The number of CT examinations showed a substantial increase for the decade, and the number of pediatric patients showed a mild decrease from 2001 to 2005, and a substantial increased since 2005 (Table 1). The overall increase of CT scans per 1000 patients from 2001 to 2010 was 92%; in detail, the number of CT scans per 1000 patients increased from 50.1 CTs in 2001 to 156.5 CTs in 2006, and then decreased to 96.0 CTs in 2010 (Table 2) (Fig. 1).

In terms of CT types by anatomic region, the majority of scans were head CTs (74.6%), followed by abdominal CTs (11.5%), facial bone CTs (10.1%), chest CTs (2.6%), miscellaneous CTs (0.7%) and cervical CTs (0.5%) (Fig. 1). Although the head CTs was the most predominant, facial bone CTs showed the largest rate of increase (3188%), followed by cervical CTs (642%), abdominal CTs (474%), miscellaneous CTs (236%), chest CTs (89%) and head CTs (39%) per 1000 patients for a decade (Fig. 2).

Increasing rate of CT utilization was more pronounced in

Table 1. Sample Characteristics according to Year

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
No. of pediatric ED patients	18228	16158	14359	13777	13380	14590	18365	23757	30132	30698	193444
0 ≤ age < 13	16539	14384	12662	12058	11651	12569	15801	20805	25943	27277	169689
13 ≤ age < 18	1689	1774	1697	1719	1729	2021	2564	2952	4189	3421	23755
No. of CT examinations	913	1349	1555	1462	1585	2283	2608	2767	2981	2947	20450
0 ≤ age < 13	743	1079	1226	1114	1137	1594	1753	1835	2043	1951	14475
13 ≤ age < 18	170	270	329	348	448	689	855	932	938	996	5975

Note.— ED = emergency department

Table 2. Number of CT Examinations per 1000 Patients in Pediatric Emergency Department according to Year

	2001	2002	2003	2004	2005	2006	Percent Increase*	2007	2008	2009	2010	Percent Increase†
No. of CTs per 1000 patients	50.1	83.5	108.3	106.1	118.5	156.5	212%	142.0	116.5	98.9	96.0	92%
0 ≤ age < 13	44.9	75.0	96.8	92.4	97.6	126.8	182%	110.9	88.2	78.7	71.5	59%
Head CTs	41.5	67.0	85.7	77.8	79.0	103.6	149%	90.0	70.4	59.9	53.7	29%
Abdomen CTs	2.2	5.8	7.6	7.0	10.6	9.5	335%	8.7	7.8	8.9	8.5	289%
Facial bone CTs	0.3	0.1	0.7	3.7	5.1	9.5	3058%	9.6	8.1	8.4	7.5	2374%
Chest CTs	0.7	1.9	2.3	3.3	1.8	3.4	372%	1.6	1.1	0.9	1.2	62%
Miscellaneous CTs	0.1	0.1	0.4	0.5	0.5	0.4	229%	0.6	0.7	0.3	0.3	143%
Cervical CTs	0.1	0.1	0.2	0.1	0.5	0.4	558%	0.4	0.2	0.3	0.4	567%
13 ≤ age < 18	100.7	152.2	193.9	202.4	259.1	340.9	239%	333.5	315.7	223.9	291.1	189%
Head CTs	85.8	128.5	147.3	144.3	146.3	193.5	125%	182.9	171.1	118.6	138.8	62%
Abdomen CTs	6.5	18.0	27.1	25.0	48.0	57.4	781%	57.7	56.6	43.0	65.2	901%
Facial bone CTs	1.8	2.3	4.7	24.4	39.3	59.4	3243%	72.9	69.8	48.5	69.9	3833%
Chest CTs	5.3	2.3	9.4	7.0	16.2	20.8	290%	13.7	10.2	9.3	10.2	92%
Miscellaneous CTs	0.6	0.6	4.7	1.2	6.4	7.4	1154%	4.7	5.8	2.1	2.9	394%
Cervical CTs	0.6	0.6	0.6	0.6	2.9	2.5	318%	1.6	2.4	2.4	4.1	591%

Note.— *Increased rate of CT scans from 2001 to 2006

= (Number of CTs per 1000 patients in 2006 - number of CTs per 1000 patients in 2001) / number of CTs per 1000 patients in 2001,

†Increased rate of CT scans from 2001 to 2010

= (Number of CTs per 1000 patients in 2010 - number of CTs per 1000 patients in 2001) / number of CTs per 1000 patients in 2001.

Fig. 1. Total number of CT scans performed for pediatric patients who visited emergency department for previous decade.

adolescents than in pediatric patients, younger than 13 years of age (189% and 59%, respectively). In adolescents, facial bone CTs exhibited the largest rate of increase (3833%), followed by abdominal CTs (901%), cervical CTs (591%), miscellaneous CTs (394%), chest CTs (92%), and head CTs (62%). In pediatric patients, younger than 13 years, facial bone CTs (2374%) showed the largest rate of increase and

Fig. 2. Increase in rate of CT examinations by anatomic regions for previous decade.

cervical CTs (567%) showed the second largest rate of increase, followed by abdominal CTs (289%), miscellaneous CTs (143%), chest CTs (62%) and head CTs (29%) (Table 2).

Of the 18346 pediatric patients, who underwent CT examinations in the ED, 8.1% of them (n = 1486) underwent CT examinations for multiple regions (number of regions = 3443) in the same day (Fig. 3). CT examinations for multiple anatomic regions in the same day performed for pediatric ED patients showed a similar pattern of increase,

Fig. 3. Number of patients who had CT examinations for single and multiple anatomic regions in same day.

with that of the overall CT examinations, which showed an increase from 2001 to 2006, and a decrease since 2006. In terms of CT types for patients who underwent multiple CTs, head CTs (49.3%) were the most common, followed by facial bone CTs (20.9%), abdominal CTs (14.0%), chest CTs (10.8%), cervical CTs (2.8%) and miscellaneous CTs (2.3%). The most common reasons for multiple CT examinations were evaluation for traumatic injuries (90%), fever focus (7%) and insufficient clinical assessment, et cetera (3%).

DISCUSSION

A few reports from Western countries have revealed an increasing use of CT examinations in pediatric ED patients during the study periods of 1995-2007 (2), 1995-2008 (3), and 2000-2006 (1). Similar to these results, our study also showed that CT examinations per 1000 patients have increased from 2001 to 2006. Factors cited for this trend included the increasing availability of CT scanners and technological improvements in scanner efficiency, as well as image resolution with the introduction of MDCT, the cost and time benefits from improved diagnosis, a general trend toward less invasive testing, and increasing concerns regarding the malpractice litigation (1-6). Since March 2005, when the MDCT was first introduced in our ED, the number of CT examinations has shown a rapid increase, compared with the previous years (Fig. 1). The number of patients who underwent multiple CT examinations on the same day also showed a marked increase at that time (Fig. 3).

However, the use of CT scans has decreased since 2006, which is worthy of note, because there has been no specific reports, regarding the trend of CT use in pediatric ED patients after 2008. The reason for the decline in the use of CT scans since 2006 has not yet been clearly determined; however, increasing concerns about the radiation exposures in the pediatric population and educational efforts regarding the limiting CT use in pediatric patients might be the possible explanations. The effective radiation doses received by children are approximately 50% higher than those received by adults, due to their smaller body size and related attenuation (7). Furthermore, the risk for cancer mortality, related to radiation from CT examinations, is considered high for pediatric patients due to the growth process in children with increased number of dividing cells and a longer lead time for the expression of cancer (8). For example, when the same radiation dose is given, a 1-year-old is 10-15 times more likely to develop cancer cells than a 50-year-old (8).

In terms of CT scans, as classified according to the body part, facial bone CTs showed the largest rate of increase, followed by cervical CTs or abdominal CTs, miscellaneous CTs, chest CTs and head CTs for both adolescent and pediatric patients younger than 13 years of age. Compared with the study by Broder et al. (1) which revealed that chest CTs and cervical CTs showed the greatest increase (435% and 366%, respectively from 2001 to 2006), our study showed a dramatic increase in the number of facial bone CTs (3188%) and cervical CTs (642%), and the increase was predominantly in adolescents. This result would be due in part to the small starting numbers of CTs in 2001, and increased use of facial bone CTs and cervical CTs may not be surprising for adolescents since more adolescents are involved in vehicle blunt trauma (9).

This study had several limitations. First, our study reported on the results from a single institution and may not reflect the patterns of use in the nation or other geographic regions. Second, we did not evaluate the severity of the disease or injury, which might be the reason that the number of CT examinations per 1000 patients showed a decrease since 2006. Third, given the small starting numbers, percentage increases over the baseline utilization may be misleading. Fourth, we simply described the number of CT examinations in pediatric ED for the decade and did not specifically evaluate the clinical usefulness or cumulative radiation doses from CT examinations. However, the primary objective of this study

was to analyze the trends of CT use in the pediatric ED in Korea. Further studies regarding medical appropriateness and radiation hazards of CT examinations for pediatric patients would be needed.

Despite its limitations, our study is the first report on the trends of CT use in the pediatric ED of Korea. We found that the number of CT scans per 1000 patients increased by 92% from 2001 to 2010 (increase was pronounced from 2001 to 2006 and the use of CT has declined since 2006). Facial bone CTs showed the greatest increase, followed by cervical CTs, abdominal CTs, miscellaneous CTs, chest CTs, and head CTs, and the increase of CT utilization was more pronounced in adolescents than in pediatric patients younger than 13 years of age.

REFERENCES

1. Broder J, Fordham LA, Warshauer DM. Increasing utilization of computed tomography in the pediatric emergency department, 2000-2006. *Emerg Radiol* 2007;14:227-232
2. Larson DB, Johnson LW, Schnell BM, Salisbury SR, Forman HP. National trends in CT use in the emergency department: 1995-2007. *Radiology* 2011;258:164-173
3. Larson DB, Johnson LW, Schnell BM, Goske MJ, Salisbury SR, Forman HP. Rising use of CT in child visits to the emergency department in the United States, 1995-2008. *Radiology* 2011;259:793-801
4. Flohr TG, Schaller S, Stierstorfer K, Bruder H, Ohnesorge BM, Schoepf UJ. Multi-detector row CT systems and image-reconstruction techniques. *Radiology* 2005;235:756-773
5. Baker LC, Atlas SW, Afendulis CC. Expanded use of imaging technology and the challenge of measuring value. *Health Aff (Millwood)* 2008;27:1467-1478
6. Lee J, Kirschner J, Pawa S, Wiener DE, Newman DH, Shah K. Computed tomography use in the adult emergency department of an academic urban hospital from 2001 to 2007. *Ann Emerg Med* 2010;56:591-596
7. Huda W. Dose and image quality in CT. *Pediatr Radiol* 2002;32:709-713; discussion 751-754
8. Brenner D, Elliston C, Hall E, Berdon W. Estimated risks of radiation-induced fatal cancer from pediatric CT. *AJR Am J Roentgenol* 2001;176:289-296
9. Prevention CfDca. Wisqars (web-based injury statistics query and reporting system) 2007. Available from: <http://www.cdc.gov/injury/wisqars/index.html>