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...
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 ≤ 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.
= (Number of CTs per 1000 patients in the year - number of CTs per 1000 patients in 2001) / number of CTs per 1000 patients in 2001.

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 | 12261 | 15801 | 18357 | 2043 | 1951 | 14475 |
| 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
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 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 183 46 pediatric patients, who underwent CT examinations in the ED, 8.1% of them (n = 14 86) underwent CT examinations for multiple regions (number of regions = 3 443) 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,
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.

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