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Analysis of Computed Tomography Scans for Radiation Safety Management in the Republic of Korea

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ABSTRACT

Background: Computed tomography (CT) scans in the Republic of Korea have spiked, reaching approximately 9 million examinations annually in 2017. CT provides significant medical benefits, but radiation exposure remains a concern. This study aims to analyze CT scans in Korea, as a basis study for radiation safety management.

Materials and Methods: The raw data of total CT scans was obtained from the Health Insurance Review & Assessment Service and analyzed by CT scan type, patients' age and sex, and medical facility type. CT scans trends were analyzed considering the disease incidence.

Results and Discussion: In 2017, CT scans accounted for 8,977,300. Usage *per capita* was 0.18 in males and 0.17 in females. CT scans increased with age until the 50- to 59-year-old groups, then decreased. CT scans were high in abdominal/pelvic (35%), chest (26%), and head (22%) regions due to higher disease rates. Head CT was most frequently used for infants and children. Abdominal/pelvic, chest, and spine CT were more frequent for older groups. The CT scans in the upper and lower extremities was high in child and juvenile groups. Chest and abdominal/pelvic CTs were higher in males, whereas spine, whole spine, and CT densitometry were higher in females. The proportion of CT scans of tertiary and general hospitals, hospitals, and clinics accounted for ≥80%, 13%, and 5%, respectively. Abdomen/pelvis, chest, and head/neck CTs were mostly conducted in tertiary and general hospitals, spine CT in hospitals and clinics, extremity CT in hospitals, and CT densitometry in clinics.

Conclusion: The trend of CT scans varied based on the incidence rate for each patient's sex and age, and serious illness diagnosis by medical facility type. The results of this study provide data and guidance for evaluating the radiation exposure of the Korean population by CT and developing management policies for medical radiation safety.

Keywords: Medical Radiation, Computed Tomography, Computed Tomography Scans, Radiation Safety, Radiation Exposure

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Introduction

Computed tomography (CT) scans have rapidly increased globally, including the Republic of Korea [1]. CT is medically very beneficial, but radiation exposure remains an issue. The radiation dose used in CT is several times higher than that in other radiography. The high radiation doses used in CT have caused increasing concerns about the occurrence of future risk of stochastic effects, including cancer [2–5]. Therefore, at present, radiation dose management in CT is crucial when considering radiation safety and public health.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) collected and analyzed data on medical radiation usage and radiation dosage used in each country through questionnaires and literature reviews [1, 6]. The worldwide annual CT scans were 35 per 1,000 individuals, and the annual effective dose *per capita* was approximately 0.3 mSv, which was assumed by data from 1997 to 2007. Further, the annual CT scans in level I countries were 127.8 per 1,000 individuals. Level 1 countries are those with at least one physician for every 1,000 people. UNSCEAR reported that the effective dose *per capita* by medical exposure increased from 0.4 mSv in 2000 to 0.62 mSv in 2008, caused by an increase in CT scans and global population. The National Council on Radiation Protection and Measurement (NCRP) analyzed the medical radiation usage in the United States (US) and its effective dose *per capita* based on the data from IMV Medical Information Division and Medicare [7, 8]. In 2016, the annual CT scans in the US were approximately 73.5 million, and the effective dose *per capita* was approximately 1.4 mSv. Health Protection Agency in the United Kingdom (UK) estimated the usage of diagnostic radiology and analyzed the effective dose *per capita* in the entire UK population using the data from national health care service questionnaires [9]. The annual CT scans in the UK were approximately 3.4 million and the effective dose was 0.27 mSv in 2008. The annual effective dose *per capita* from diagnostic radiology in the UK was 0.4 mSv, which is lower than that in other countries, including the US. This is attributed to the early evaluation and radiation dose management from medical radiation [1, 9]. A study in the Japanese population used CT data from one state to estimate the nationwide number of patients who underwent CT and the collective dose [10]. The information on CT scans and radiation dose was collected via a survey conducted in one state, having an age distribution similar to that of Japan. In 2008, the total number of patients who underwent CT was 29 million in Japan, and the evaluated collective dose based on this was 277,400 person–Sv. Some studies analyzing CT scans in the Republic of Korea have been conducted in a single hospital, using some sample data, and on one CT type. Kim and Lim [11] obtained data from 1979 to 2009 recorded at a university hospital in Korea and analyzed the trend for usage by CT type and year. Oh et al. [12] analyzed CT scans and its percentage by year and by scan region of adult patients admitted to the emergency room, based on the data from the emergency room of a university hospital recorded from 2001 to 2010. Park [13] analyzed CT scans and proportion changes in abdominal CT scans with contrast from 2007 to 2011, according to patients' age and sex, admission and outpatient visits, and medical facility type. Park et al. [14] extracted 13% of inpatient data and 1% of outpatient data from Korean patient samples in 2009. Based on this, they analyzed the percentage of brain CT scans in patients with head injury in terms of patients' age and sex and time of visit [14].

Recently, managing radiation doses from CT has appeared as a major issue in the field of radiation safety; thus, clarifying the current situation with the highest priority for ensuring the management of medical radiation safety is necessary. To achieve this, the status of the national CT scans and radiation dose needs to be identified. In previous Korean studies, the usage data for a single hospital, or data for some specific CT examinations have been utilized to analyze CT scans. However, the total usage data of the entire Korean population should be utilized for analyzing the national CT scans.

The present study aims to analyze CT scans in the Republic of Korea as a basis study for the radiation safety management of CT. We collected the total raw data on CT scans in Korea from the Health Insurance Review & Assessment Service (HIRA) and analyzed the CT scans by CT scan type, patients' sex and age, and medical facility type. Additionally, the reasons for trend of the CT scans were analyzed considering the differences in patients' diseases and diagnoses. The results of this study provide data and guidance for assessing the radiation dose of the Korean population by CT and developing policies for medical radiation safety.

Materials and Methods

1. Collection of Raw Data on Total CT scans

The total raw data on CT scans as of 2017 were collected from HIRA, which is an institution that reviews the claim and application of the national health insurance of medical practice and possesses the information on medical radiology usage, including CT performed in the Republic of Korea. Furthermore, these raw data include both diagnostic CT and CT for radiotherapy purposes. HIRA manages medical practices by categorizing them with the medical practice code. In particular, the code HA451 refers to non–contrast head CT [15]. The collected raw data from HIRA included medical practice code, sex, age, medical facility, and usage. Age in the data was classified into different groups, with an interval of 5 years,

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from 0 to ≥85 years. Medical facility types in the data were categorized as tertiary and general hospitals (including certified tertiary hospitals and general hospitals), hospitals (including hospitals, nursing hospitals, and dental hospitals), and clinics (including clinics, dental clinics, and health institutions). Medical facilities in the Republic of Korea were classified with the following criteria. General hospitals should be equipped with ≥100 beds, have ≥7 treatment departments, and have a medical specialist exclusively appointed for each treatment department. Tertiary hospitals are general hospitals that specialize in high-level treatment for severe diseases and are selected as tertiary hospitals among general hospitals after appropriate evaluation. Hospitals should be equipped with ≥30 beds, and nursing hospitals should be equipped with beds meant for patients requiring medical care with long-term hospitalization. Additionally, clinics are medical institutions with <30 beds.

2. Establishment of CT Examination Classification

A system for CT examination classification was developed to analyze the collected CT scans data by body region and method of CT scan based on medical practices of HIRA. HIRA classifies CT into 60 subcategories [15]. This study grouped some subcategories by scan body region and method for CT scans analysis. Table 1 shows the established classification system of CT assessments for data analysis. The classified CT categories include head, neck, chest, abdomen and pelvis, spine, whole spine, extremities, CT densitometry, and interventional CT. Specific examinations are given for each CT category.

3. Analysis of CT Scans

We analyzed CT scans with the raw data based on the established CT classification system. CT scans by patients' age and sex and medical facility type were analyzed. The age groups were set as infant (0–4 years), child (5–14 years), juvenile (15–19 years), youth (20–29 years), early middle age (30–39 years), late adulthood (40–64 years), and old age (≥65 years). Additionally, the usage proportion following the CT category and usage *per capita* by age and sex were estimated. The estimated population of the Republic of Korea in 2017 was utilized while estimating the usage *per capita* [16]. The usage of CT was estimated by tertiary and general hospitals, hospitals, and clinics in the case of the type of medical facility. The reasons for CT scans trend were analyzed considering the disease incidence by patients' age and sex and diagnosis performed mainly by the medical facility. The statistical data on the number of patients with a specific disease, which had been previously investigated in Korea, were utilized to analyze the reasons for the CT scans trend.

Table 1. Classification System of Computed Tomography Examinations for Data Analysis

CT category	Specific examination	Included examination
Head	Head Face or skull base Sinus Orbit Temporal bone Other head scans	Scan using a contrast agent Scan not using a contrast agent Limited CT Etc. Double CT Triple CT 3D CT CT angiography Articular canal or intra-cavity imaging Cine CT Cerebral CT
Neck	Neck	
Chest	Chest High-resolution chest CT	
Abdomen/Pelvis	Abdomen/Pelvis	
Spine	Spine	
Whole spine	Whole spine	
Extremities	Upper extremity Lower extremity	
CT densitometry	QCT	QCT pQCT
Interventional CT	Head Neck Chest Abdomen Spine Whole spine Upper extremity Lower extremity	CT to guide intervention

CT, computed tomography; 3D, three dimensional; QCT, quantitative computed tomography; pQCT, peripheral quantitative computed tomography.

Results and Discussion

The type of CT scan, patients' age and sex, and medical facility types were analyzed from the total raw data on CT scans obtained from HIRA. Furthermore, the reasons for CT scans trend were analyzed considering the disease prevalence by patients' age and sex, and diagnoses were performed mainly by the medical facility.

1. Analysis of CT Scans by Patients' Sex

Table 2 presents the number of CT scans by patients' sex for each CT category. As of 2017, 8,977,300 CT scans were recorded. By sex, the number of CT scans is 4,632,428 (51.6% of total) in males and 4,344,872 (48.4% of total) in females, which is approximately 6.6% higher in males than in females. CT scans are relatively high in abdominal and pelvic (34.5%), chest (25.7%), and head (22.3%) regions in both males and females. CT scans on the body regions account for 82.5% of the total because CT was generally utilized in diagnosing severe diseases, which are more likely to occur in the abdomen, pelvis, thorax, and head than in the extremities. Chest and abdominal/pelvis CT scans in males exceed >10% higher than that in females. The usages of spine, whole spine, and CT densitometry are higher in females; especially, CT densitometry usage is approximately 6.7 times higher in females. This is because disease incidence trends vary by sex, and the type of CT scan required for diagnosis also depends on the specific disease. Chest CT is performed to diagnose diseases such as lung cancer, chronic pulmonary diseases, and ischemic heart disease. The number of male patients with lung cancer, chronic pulmonary diseases, and ischemic heart disease was 1.8, 2.5, and 1.4 times higher, respectively, than those of female patients as of 2016 in the Republic of Korea [17]. Abdominal and pelvic CT is generally used to diagnose gastrointestinal cancer and diseases, including stomach cancer, colorectal cancer, liver cancer, and urinary stones. Data on the number of patients classified by the disease prevalence, as of 2016 in Korea, indicated that the number of male patients with stomach cancer, colorectal cancer, and liver cancer was >2, 2.9, and 1.5 times higher, respectively, than that of female patients [17]. The number of male and female patients with urinary stones in 2014 was 1.3 million and 0.88 million, respectively, which is approximately 1.5 times higher in male patients [17, 18]. Spine or whole spine CT was performed to diagnose spinal diseases, such as herniated discs and spinal stenosis. CT densitometry was conducted to diagnose osteoporosis. In Korea, the number of female patients with spinal diseases was 1.4 times higher in 2014 and that with osteoporosis was 1.5 times higher in 2016 than male patients [17, 19].

Table 2. Number of Computed Tomography Scans by Patients' Sex for Each Computed Tomography Category

CT category	Number of scans by sex (%)		
	Total	Male	Female
Head	2,003,414 (22.3)	1,028,899 (22.2)	974,515 (22.4)
Neck	277,851 (3.1)	141,539 (3.1)	136,312 (3.1)
Chest	2,309,642 (25.7)	1,230,905 (26.6)	1,078,737 (24.8)
Abdomen/Pelvis	3,096,527 (34.5)	1,629,923 (35.2)	1,466,604 (33.8)
Spine	664,065 (7.4)	315,690 (6.8)	348,375 (8.0)
Whole spine	26,989 (0.3)	12,060 (0.3)	14,929 (0.3)
Upper extremity	214,525 (2.4)	116,482 (2.5)	98,043 (2.3)
Lower extremity	298,339 (3.3)	145,693 (3.1)	152,646 (3.5)
CT densitometry	85,822 (1.0)	11,159 (0.2)	74,663 (1.7)
Interventional CT	126 (0.001)	78 (0.002)	48 (0.001)
Total	8,977,300 (100)	4,632,428 (100)	4,344,872 (100)

CT, computed tomography.

2. Analysis of CT Scans by Patients' Age

Table 3 shows the number of CT scans by patient's age for each CT category. The CT scans of the old age groups (≥65 years) and late middle age groups (50–64 years) are relatively high, with 3,401,746 cases (37.9% of the total) and 2,932,128 cases (32.7% of the total), respectively. The usage in the minor groups (0–19-year-olds) is 377,437 cases, accounting for approximately 4.2% of the total. The percentage of head CT decreases and that of abdominal/pelvic, chest, spine, and CT densitometry increases in groups with older ages in the case of the CT category. Additionally, the percentage trend by CT category is similar in groups older than the middle-aged adult groups. The percentage of head CT is the highest in infants and child groups in terms of the percentage of usage by age.

Table 3. Number of Computed Tomography Scans by Patients' Age for Each Computed Tomography Category

CT category	Number of scans by age (%)						
	Infant (0–4 years)	Child (5–14 years)	Juvenile (15–19 years)	Youth (20–29 years)	Early middle (30–49 years)	Late middle (50–64 years)	Old age (≥65 years)
Head	38,848 (72.7)	73,940 (47.2)	61,167 (36.5)	135,458 (30.5)	409,219 (22.5)	561,687 (19.2)	723,095 (21.3)
Neck	1,637 (3.1)	4,152 (2.7)	5,660 (3.4)	19,971 (4.5)	72,122 (4.0)	92,895 (3.2)	81,414 (2.4)
Chest	5,652 (10.6)	8,566 (5.5)	19,999 (11.9)	55,109 (12.4)	375,522 (20.6)	807,223 (27.5)	1,037,571 (30.5)
Abdomen/Pelvis	4,081 (7.6)	33,047 (21.1)	47,883 (28.6)	148,669 (33.5)	680,637 (37.4)	1,062,226 (36.2)	1,119,984 (32.9)
Spine	371 (0.7)	2,984 (1.9)	8,831 (5.3)	39,477 (8.9)	172,204 (9.5)	234,024 (8.0)	206,174 (6.1)
Whole spine	44 (0.1)	302 (0.2)	534 (0.3)	1,457 (0.3)	5,357 (0.3)	7,980 (0.3)	11,315 (0.3)
Upper extremity	1,940 (3.6)	18,574 (11.9)	11,307 (6.8)	20,800 (4.7)	46,623 (2.6)	62,607 (2.1)	52,674 (1.5)
Lower extremity	868 (1.6)	14,964 (9.6)	12,070 (7.2)	22,916 (5.2)	57,890 (3.2)	82,789 (2.8)	106,842 (3.1)
CT densitometry	- (0)	2 (<0.001)	14 (<0.001)	51 (0.01)	2,501 (0.1)	20,656 (0.7)	62,598 (1.8)
Interventional CT	- (0)	- (0)	- (0)	1 (<0.001)	5 (<0.001)	41 (0.001)	79 (0.002)
Total	53,441 (100)	156,531 (100)	167,465 (100)	443,909 (100)	1,822,080 (100)	2,932,128 (100)	3,401,746 (100)

CT, computed tomography.

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This is because head injury frequently occurs by falling and traffic accidents in the infant and child groups [20, 21]. Magnetic resonance imaging can be performed for diagnosing head trauma, but a rapid diagnosis is imperative because infants have an immature central nervous system. Therefore, CT, which is rapid and less likely to be distorted by movement, is mainly utilized for diagnosing head trauma in children [22–24]. Furthermore, the percentages of abdominal/pelvic, chest, and spine CT scans are higher in older age groups because the incidence rate of various cancer types, pulmonary diseases, heart diseases, spinal diseases, and osteoporosis increased in such age groups. Moreover, CT scans in the upper and lower extremities are relatively higher in the child and juvenile groups than in the infants and adults groups. This is because upper and lower extremity fractures are likely to occur in these age groups due to frequent outdoor activities and exercises. The number of fracture incidences of upper and lower extremities in the 10–19 years age groups from 2008 to 2010 in the Republic of Korea accounts for approximately 76% of the total fractures of the minor groups population [25]. Furthermore, CT scans in the upper extremities are slightly higher than in the lower extremities in the child groups. This is because upper extremity fractures are more predominant than lower extremity fractures in the child groups, as the upper extremity absorbs the impact upon falling [25–27].

3. Analysis of CT Scans by Patients' Age/Sex and CT Scans *per Capita*

Fig. 1 illustrates the percentage of CT scans and CT scans *per capita* by patients' age and sex. The statistics are presented for total CT scans, spine/whole spine CT, upper/lower extremity CT, and CT bone densitometry. CT scans exhibited comparable trends on the spine and whole spine and upper and lower extremities. Therefore, CT scans on the spine and the whole spine were combined. The same was for the upper and lower extremities. The percentage of entire CT scans increases with rising age until the 50–59 years age groups, which decrease afterward. The percentage of CT scans in the 50s to 60s age groups is relatively high, accounting for approximately 43% of total usage. The percentage of CT scans in <74 years age group is higher in males than in females, whereas CT scans in ≥75 years age groups are higher in females than in males. This is because the population of females in the ≥75 years age groups was 40% higher than that of males. The average CT scans *per capita* as of 2017 are 0.17 (0.18 in males and 0.17 in females). The usage *per capita* by aged ≥50 years is higher than average CT scans. The usage *per capita* in the 80–84 years age group is 0.71 in males and 0.48 for females, and the CT scans *per capita* in males are approximately 50% higher than in females in individuals in the age group. The CT scans *per capita* increase as age increases in both males and females. However, CT scans *per capita* decrease for females aged ≥85 years compared to the younger age groups because of the small rate of increase of usage relatively as compared to the decrease in population by increasing in age. The difference in population in each age group by sex causes the high CT scans *per capita* in the older age groups of males than females. The population of females in their 70s and >80s is 1.3 times and 2.2 times higher, respectively than those of males as of 2017 in the Republic of Korea [16].

The percentage of spine and whole spine CT scans increases until the 59 years age group with increasing age, which decreases afterward. The 50s–60s age groups account for 45% of spine and whole spine CT scans. The percentage of CT scans for spine and whole spine CT in total age groups indicates a higher percentage for females (53%) than for males (47%). The percentage of spine and whole spine CT scans is higher in males than in females until 49 years of age, but the percentage of CT scans is higher in females in the ≥50 years age groups. This is related to the difference in the number of patients with spinal disease incidence by age and sex. The number of patients with spinal diseases in the 50s and 60s accounts for approximately 38% of the total number of patients. Furthermore, the proportion of female patients is 50% higher than that of male patients in the 50s age groups [19]. Spine and whole spine CT scans *per capita* are approximately 0.013 as of 2017. The CT scans *per capita* are higher than the average in both males and females at ≥45 years age groups. Additionally, the CT scans *per capita* of females exceede that of males from the 50s age groups. The CT scans *per capita* in the ≥85 years age groups are higher in males than in females, caused by their decreased population of males.

The percentage of CT scans in the upper and lower extremities is twice higher in the 10–14 years age group than in the younger age groups, which further increases until the 59 years age group and ultimately decreases sharply in the >80 years age groups. The percentage of CT scans in the upper and lower extremities for 10–19 years age groups accounts for 10% of the total CT scans in extremities. Additionally, the percentage of CT scans in extremities in males is higher than that in females until 49 years of age, which is thrice higher in males than in females, especially in the 10–19 years age groups.

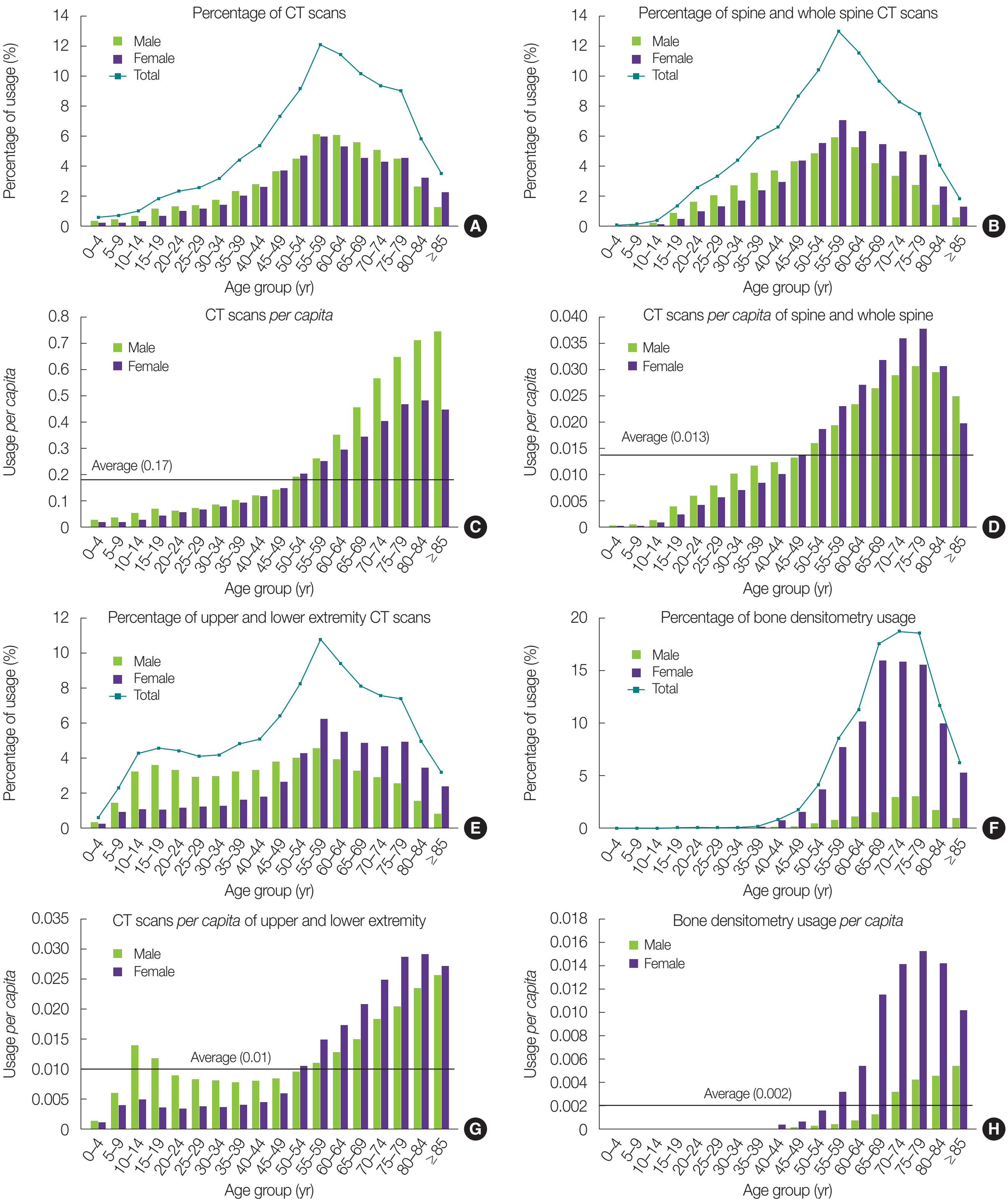

Fig. 1. Percentage of computed tomography (CT) scans (upper figure) and CT scans *per capita* (lower figure) by patients' age and sex. The statistics are presented for total CT scans, spine/whole spine CT, upper/lower extremity CT, and CT bone densitometry. (A) Percentage of CT scans. (B) Percentage of spine and whole spine CT scans. (C) CT scans *per capita*. (D) CT scans *per capita* of spine and whole spine. (E) Percentage of upper and lower extremity CT scans. (F) Percentage of bone densitometry usage. (G) CT scans *per capita* of upper and lower extremity. (H) Bone densitometry usage *per capita*.

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Furthermore, the CT scans proportion in females started to increase sharply from 59 years of age, which is 1.4 times higher than that of males, and eventually decreases from ≥80 years of age. The CT scans proportion being higher in males in their 10s can be because they are more likely to have upper and lower extremity fractures due to outdoor activities and exercises. The number of patients diagnosed with fractures from 2008 to 2010 is approximately 2.8 times higher in males than in females, and 98% among them are upper and lower extremity fractures [17, 25]. The high usage of females in the ≥59 years age groups is due to the increased incidences of osteoporosis, and the decrease in the proportion of CT scans in females aged >80 years is due to the decreased number of patients with fractures related to mortality. The number of female patients with fractures in their 60s, 70s, and 80s is approximately 190,000, 180,000, and 110,000, respectively, in 2016, wherein the number is relatively low for females in their 80s [17]. The CT scans *per capita* of upper and lower extremities are on average 0.01. The CT scans *per capita* of upper and lower extremities by each age group in 10–19-year-old males and ≥55-year-old males and females are higher than the average, because of a high percentage of usage in those age groups. Additionally, the CT scans *per capita* of the upper and lower extremities of males increase in the 45–85 years age groups due to a decrease in the population, whereas the CT scans *per capita* of females decrease in the ≥85 years age groups.

The percentage of CT densitometry usage increases from the 50s age groups, in which osteoporosis starts to occur, and continues to increase until the 74 years age group. However, it decreases sharply at and after 80 years of age. The percentage of CT densitometry usage in the 65–79 years age groups is higher than that in the other age groups, accounting for approximately 55% of the total. The percentage of CT scans by females accounts for most of the CT densitometry usage (87%) in the case of usage by sex. Moreover, the percentage of CT scans in the 65–79 years age groups is the highest in both males and females, associated with the increase in the number of patients with osteoporosis in those age groups. The number of patients with osteoporosis in the 50s age groups is 2.8 times and 7.5 times higher in males and females, respectively, compared with those in the 40s age groups in the Republic of Korea. The number of female and male patients in their 60s and 70s accounted for >60% of the total, which sharply declines after 80 years of age due to mortality [17]. The average CT densitometry usage *per capita* is 0.002 cases, including <0.001 and 0.003 cases in males and females, respectively, which differes greatly. CT densitometry usage *per capita* by age group increases sharply in the ≥65 years age groups, wherein the percentage of usage sharply increases, and it decreases in the ≥80 years age groups, wherein the percentage of usage decreases. Moreover, the usage *per capita* in males tends to increase up to 85 years due to a decrease in the population, whereas the usage *per capita* in females decreases from 80 years.

4. Analysis of CT Scans by Medical Facility Type

Table 4 presents the number of CT scans by medical facility type for each CT category. The proportion of CT scans of tertiary and general hospitals, hospitals, and clinics accounts for ≥80%, 13%, and 5%, respectively. The percentage of CT scans in tertiary and general hospitals is highest because CT is generally utilized for diagnosing severe diseases, which are typically treated in tertiary and general hospitals.

The percentage of CT scans in tertiary and general hospitals is relatively high for abdomen/pelvis, chest, and head/neck scans among the medical facility types. However, the relative proportion of CT scans compared with hospital and clinic is lower at spine, whole spine, extremity, and CT densitometry. The percentage of CT scans is the highest at the spine with relatively high at the abdominal/pelvic, chest, and head in the hospital and clinic. The relative proportion of CT scans is higher at extremity CT in the hospital and CT densitometry in the clinic.

The CT scans trends were associated with the diseases. Abdominal/pelvic, chest, and head CT scans in tertiary and

Table 4. Number of Computed Tomography Scans by Medical Facility Type for Each Computed Tomography Category

CT category	Number of scans by type of medical facility (%)		
	Tertiary & General hospital	Hospital	Clinic
Head	1,718,483 (23.7)	211,663 (17.7)	73,268 (13.6)
Neck	262,025 (3.6)	10,005 (0.8)	5,821 (1.1)
Chest	1,983,729 (27.4)	197,105 (16.5)	128,808 (23.9)
Abdomen/Pelvis	2,734,739 (37.8)	230,471 (19.2)	131,317 (24.3)
Spine	202,948 (2.8)	321,432 (26.8)	139,685 (25.9)
Whole spine	15,190 (0.2)	10,042 (0.8)	1,757 (0.3)
Upper extremity	118,458 (1.6)	82,079 (6.9)	13,988 (2.6)
Lower extremity	191,232 (2.6)	89,700 (7.5)	17,407 (3.2)
CT densitometry	13,411 (0.2)	44,800 (3.7)	27,611 (5.1)
Interventional CT	121 (0.002)	5 (<0.001)	- (0)
Total	7,240,336 (100)	1,197,302 (100)	539,662 (100)

CT, computed tomography.

general hospitals accounted for 90% because diseases that are diagnosed using those scans are typically treated in tertiary and general hospitals due to their severity. Over 70% of the number of patients with cerebrovascular disease, intracranial injury, gastrointestinal cancer, and ischemic heart disease, which are diagnosed using head, chest, and abdominal and pelvic CT were treated in tertiary and general hospitals in 2014 [28]. Additionally, diseases that used the highest cases of CT for diagnosis in tertiary and general hospitals in 2007 were cancers, including stomach and liver cancer, cerebral infarction, and skull fracture [29]. The high percentage of spine and upper and lower extremity CT and CT densitometry usage in hospitals and clinics compared with that in tertiary and general hospitals can be attributed to spinal diseases, which are mostly chronic, and osteoporosis, which are usually treated in hospitals and clinics. Intervertebral disc disorder and other spinal diseases used the highest cases of CT for diagnosis in 2007 [29]. In particular, the high percentage of spine CT scans in hospitals was because spinal surgeries are typically performed in hospitals. The number of spinal surgeries in hospitals in 2014 accounted for approximately > 50% of the total usage [19].

Conclusion

CT scans in the Republic of Korea were analyzed as a basis study for radiation safety management and radiation dose estimation. The raw data of total CT scans in Korea were collected and analyzed by CT scan type, patients' age and sex, and medical facility type. Moreover, the reasons for CT scans trends were analyzed considering the disease incidence by patients' age and sex and diagnoses performed by the medical facility.

The total number of CT scans in 2017 was 8,977,300 (approximately 52% in males and 48% in females). CT scans *per capita* by sex was 0.18 in males and 0.17 in females, with an average for sex of 0.17. This result is lower compared to CT scans *per capita* in the US, which were 0.23 as of 2016. CT scans *per capita* were 0.71 in males and 0.48 for females, approximately 50% higher in males, in the 80–84 years age group. CT scans increased until the 50–59 years age groups with increasing age, after which it decreased. CT scans of the old age groups (≥65 years) and late middle age groups (50–64 years) were relatively high, with approximately 38% and 33% of the total, respectively. The usage in the minor groups (0–19 years) was approximately 4% of the total.

CT scans were relatively high in abdominal and pelvic (35%), chest (26%), and head (22%) regions in both males and females. Head CT was most frequently utilized because head injury frequently occurs from falling and traffic accidents in the groups for the infants and child groups. Abdominal/pelvic, chest, and spine CT scans for older age groups were more frequent because the incidence rate of various cancer types, pulmonary diseases, heart diseases, and others increased in such age groups. The CT scans in the upper and lower extremities were relatively higher in the child and juvenile groups than in infants and adults.

Chest and abdominal/pelvis CT scans were higher in males and the CT scans on the spine, whole spine, and CT densitometry were higher in females. This is because the disease incidence that each scan type is used to diagnose is different in each sex. In particular, chest CT is utilized to diagnose diseases, including lung cancer, chronic pulmonary diseases, and ischemic heart diseases. The number of male patients with lung cancer, chronic pulmonary diseases, and ischemic heart diseases was higher than the number of female patients in Korea. Spine and whole spine CT scans were approximately half of the total in the 50s to 60s age groups and more predominantly used in females. This is because of the difference in the number of patients with spinal disease incidence by age and sex. Upper and lower extremity CT scans in males were approximately three times higher than that in females for the 10–14 years age group. CT densitometry usage was approximately three times higher in females than in males for the 65–69 years age group.

The proportion of CT scans of tertiary and general hospitals, hospitals, and clinics accounted for ≥80%, 13%, and 5%, respectively. Abdomen/pelvis, chest, and head/neck scan usage were more frequently performed in tertiary and general hospitals among the medical facility types. Spine CT, extremity CT, and CT densitometry usage were highest in usage in hospitals and clinics, hospitals, and clinics, respectively. CT scans trends were associated with the diseases.

Comprehensively, the trend of CT scans varied based on the incidence rate for patients' sex and age, and diagnosis for serious illness by medical facility type. The highest priority should be given to first reviewing the current status of CT scans to achieve medical radiation safety management. The results of this CT scans analysis provide data and guidance for assessing the radiation exposure of the Korean population by CT and developing management policies for medical radiation safety.

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Ethical Statement

This study analyzed data according to the CT scan type, patients' age and sex, and medical facility type. CT scan trends were analyzed considering the disease incidence. The raw data were provided by the Health Insurance Review and Assessment Service (HIRA) and were anonymized to protect personal information. No individual identifiers were included in the dataset. Therefore, Institutional Review Board (IRB) approval was not required for this research, in accordance with ethical guidelines.

Author Contribution

Conceptualization: Kim KP. Methodology: Kim KP. Data curation: Lee MY, Oh GE, Son GW. Formal analysis: Kim KP. Funding acquisition: Kim KP. Investigation: Lee MY, Kim KP. Visualization: Lee MY, Kim JW. Software: Lee MY, Kim KP. Validation: Kim KP. Writing - original draft: Lee MY, Kim KP. Writing - review & editing: Kim KP. Approval of final manuscript: all authors.

References

1. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. UNSCEAR; 2008.
2. Berrington de Gonzalez A, Kim KP, Knudsen AB, Lansdorp-Vogelaar I, Rutter CM, Smith-Bindman R, et al. Radiation-related cancer risks from CT colonography screening: a risk-benefit analysis. AJR Am J Roentgenol. 2011;196(4):816–823.
3. Brenner DJ, Hall EJ. Computed tomography: an increasing source of radiation exposure. N Engl J Med. 2007;357(22):2277–2284.
4. Brenner DJ, Elliston CD. Estimated radiation risks potentially associated with full-body CT screening. Radiology. 2004;232(3):735–738.
5. Hart D, Wall BF. UK population dose from medical X-ray examinations. Eur J Radiol. 2004;50(3):285–291.
6. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. UNSCEAR; 2000.
7. National Council on Radiation Protection and Measurements. Ionizing radiation exposure of the population of the United States. NCRP; 2009.
8. National Council on Radiation Protection and Measurements. Medical radiation exposure of patients in the United States. NCRP; 2019.
9. Hart D, Wall BF, Hillier MC, Shrimpton PC. Frequency and collective dose for medical and dental X-ray examinations in the UK, 2008 [Internet]. Health Protection Agency; 2010 [cited 2024 Sep 25]. Available from: https://assets.publishing.service.gov.uk/media/5a7d618440f0b60a7f1aa285/HPA-CRCE-012_for_website.pdf
10. Tsushima Y, Taketomi-Takahashi A, Takei H, Otake H, Endo K. Radiation exposure from CT examinations in Japan. BMC Med Imaging. 2010;10:24.
11. Kim MC, Lim CH. Computed tomography by frequency of test. J Korean Soc of Comput Tomogr Technol. 2011;13(1):137–148 (Korean).
12. Oh HY, Kim EY, Cho J, Yang HJ, Kim JH, Kim HS, et al. Trends of CT use in the adult emergency department in a tertiary academic hospital of Korea during 2001-2010. Korean J Radiol. 2012;13(5):536–540.
13. Park YT. Analysis of recent medical trends of computational tomography using contrast medium. HIRA. 2012;6:46–56 (Korean).
14. Park SY, Jung JY, Kwak YH, Kim DK, Suh DB. A nationwide study on the epidemiology of head trauma and the utilization of computed tomography in Korea. J Trauma Inj. 2012;25(4):152–158 (Korean).
15. Health Insurance Review & Assessment Service. Health insurance benefit costs (February 2017 edition) [Internet]. HIRA; 2017 [cited 2024 Sep 25]. Available from: https://repository.hira.or.kr/handle/2019.oak/2120 (Korean).
16. Korean Statistical Information Service. Population census [Internet]. Statistics Korea; 2024 [cited 2024 Sep 25]. Available from: https://kosis.kr/statisticsList/statisticsListIndex.do?menuId=M_01_01&vwcd=MT_ZTITLE&parmTabId=M_01_01&parentId=A.1;A_6.2;#A_6.2 (Korean).
17. Health Insurance Review & Assessment Service. 100 Disease statistics in living [Internet]. HIRA; 2018 [cited 2024 Sep 25]. Available from: https://repository.hira.or.kr/handle/2019.oak/1273 (Korean).
18. Ko WJ, Jung JH, Han HH, Hong JH. An analysis of the occurrence

and treatment pattern of urinary calculus [Internet]. National Health Insurance Service Ilsan Hospital Institute of Health Insurance & Clinical Research; 2016 [cited 2024 Sep 25]. Available from: https://repository.nhimc.or.kr/bitstream/2023.oak/113/2/2016-20-027.pdf (Korean).
19. Health Insurance Review & Assessment Service. In 2014, 1 in 4 Koreans were treated for spinal disease [Internet]. HIRA; 2015 [cited 2024 Sep 25]. Available from: http://www.hira.or.kr/bbsDummy.do?pgmid=HIRAA020041000100&brdScnBltNo=4&brdBltNo=9054 (Korean).
20. Kraus JF, Fife D, Cox P, Ramstein K, Conroy C. Incidence, severity, and external causes of pediatric brain injury. Am J Dis Child. 1986;140(7):687–693.
21. Ryu MS, Lee KS. Traumatic brain injury in childhood. J Korean Child Neurol Soc. 2006;14(1):87–93 (Korean).
22. Giza CC, Mink RB, Madikians A. Pediatric traumatic brain injury: not just little adults. Curr Opin Crit Care. 2007;13(2):143–152.
23. Maguire JL, Boutis K, Uleryk EM, Laupacis A, Parkin PC. Should a head-injured child receive a head CT scan? A systematic review of clinical prediction rules. Pediatrics. 2009;124(1):e145–e154.
24. Jo HJ, Lim YS, Kim JJ, Cho JS, Hyun SY, Yang HJ, et al. Value of repeat brain computed tomography in children with traumatic brain injury. J. Trauma Inj. 2015;28(3):149–157 (Korean).
25. Kwon YW, Lee SH, Kim HW, Hwang JH. The pattern of occurrence of fractures in children and adolescents and its managements based on the database of the health insurance review and assessment service. J Korean Fract Soc. 2014;27(4):308–314 (Korean).
26. Kang MS, Kim HS. Characteristics and trends of traumatic injuries in children visiting emergency departments in South Korea: a retrospective serial cross-sectional study using both nationwide-sample and single-institutional data. PLoS One. 2019;14(8):e0220798.
27. Sugimori H. Epidemiology of fractures in Japanese children and adolescents. Clin Calcium. 2005;15(8):1347–1353 (Japanese).
28. Korea Information Classification of Diseases. A00-B99 I: Certain infectious and parasitic diseases [Internet]. KOICD; 2015 [cited 2024 Sep 25]. Available from: https://www.koicd.kr/stt/statDisease.do (Korean).
29. Health Insurance Review & Assessment Service. Analysis results of CT claim status in 2007 [Internet]. HIRA; 2008 [cited 2024 Sep 25]. Available from: https://www.kmoc.or.kr/home/mengmoksa_board/data/new4/admin8020090128103440.pdf (Korean).

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