Estimation of the number of total and pediatric CT procedures based on a nationwide survey in Japan

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Abstract. A nationwide survey was conducted to determine the frequency of CT procedures in Japan in 2007. The frequency of adult and pediatric CT scans was estimated using a model based on the results of the survey. Survey questionnaires were sent to 2266 CT facilities: 1068 government hospitals, and 1198 other hospitals and non-hospital medical centers. The questionnaire requested information including the number of beds, outpatients per day, type of CT scanner, various body regions scannced, and the number of scans performed**.** Body regions scanned were classified into 35 regions. The duration of the investigation was 2 days for adults and 7 days for children. Patients were classified into one of six age categories: 0–3 months, 4–11 months, 1–4 years, 5–9 years, 10–15 years, or adult. The results of the study indicate that the number of CT procedures was closely correlated with the number of hospital beds. We estimate that approximately 20.5 million procedures were performed in 2005, and 21.2 million in 2006. The number of pediatric CT procedures was calculated by multiplying the total number of CT procedures by the estimated fraction of pediatric (0–15 years) CT procedures. Annual pediatric CT procedures were estimated to have been approximately 580,000 in 2005 and 600,000 in 2006. The present study indicates that the number of procedures per capita, for both total CT and pediatric CT, is lower in Japan than in the

USA.

Key Words: CT, pediatric, medical exposure, low-dose risk, Japan

Introduction

The National Council on Radiation Protection (NCRP) reported that CT exposure constituted nearly 24% of the total radiation exposure in the USA from all sources in 2006 [1]. Taking into account relative populations, Hall and Brenner [2] reported that the number of CT procedures per person is five times greater in the USA than in the UK. It is estimated that approximately 3 million CT procedures were performed per year in the UK in 2005–2006, compared with 0.25 million in 1980. There were 69 million scans in the USA in 2007, compared with approximately 2 million in 1980 [2, 3]. Pediatric CT usage in particular has shown a rapid increase. In 1989, pediatric scans accounted for approximately 4% of all CT scans [4], rising to approximately 6% in 1993 [5]. According to IMV Medical Information Division, Inc., CT market summary report, 8–10% of all CT procedures performed in the USA between 2004 and 2006 were pediatric procedures [1, 6, 7]. However, the NCRP reported that the number of procedures for pediatric cases could not be determined separately because of the unavailability of detailed information regarding the distribution of CT categories within the pediatric population [1]. Based on a nationwide survey in Japan in 2000, Nishizawa [8] estimated that the annual number of CT examinations was 1.14 million for those aged 0–14 years, 35.4 million for those aged 15 years and older, and 36.5 million in total. Miyazaki [9] estimated 1.22 million pediatric CT procedures for those aged 0–15 years in Japan in 2003.

An estimation scheme was devised in the UK [10] as a national survey of dose from CT.

Similar surveys regarding CT procedures have been conducted in many other countries [2, 11–13]. In the present study, we conducted a nationwide survey regarding CT procedures performed in 2005 and 2006, with the aim of estimating trends in the frequency of CT procedures in Japan to predict the potential health risk due to CT.

Materials and methods

A survey questionnaire was sent to 2266 hospitals, including general practitioners and radiology institutes. Of these facilities, 1068 were governmental hospitals (university hospitals, prefectural and city government hospitals, National Hospital Organization medical centers, Red Cross hospitals, Federation of National Public Services, and affiliated personal mutual aid associations, etc.), and 1198 were other hospitals and non-hospital medical centers. We conducted the survey between October 2007 and February 2008. The survey questionnaire requested information including the following: number of beds, outpatients per day, type of CT scanner, body regions scanned, and procedures undertaken annually in 2005 and 2006. Body regions were classified into 35 regions (head 1-2 scan, sinus 1-2 scan, head to pelvis 1-2 scan, neck 1-2 scan, neck and chest 1-2 scan, neck and abdomen 1-2 scan, neck to pelvis 1-2 scan, chest 1-2 scan, chest and HRCT, chest and abdomen 1-2 scan, chest to pelvis 1-2 scan, abdomen 1-4 scan, abdomen and pelvis 1-2 scan, etc). The duration of the investigation was 2 days for adults and 7 days for children. Patients were classified into one of six age categories: 0–3 months, 4–11 months, 1–4 years, 5–9 years, 10–15 years, or adult.

Based on information gained from the questionnaire and other data, a trend analysis

was conducted to estimate the frequency of CT procedures for the total national population and for the pediatric population. We examined the relationship of the frequency of CT procedures to the number of beds or outpatients, the number of CT detectors, and the number of CT machines per facility.

Results

Survey

Among the 2266 solicited CT facilities, we received 418 responses (18.4%). Of the governmental hospitals solicited, 293 (27.4%) responded, while 125 (10.4%) of the general hospitals and non-hospital medical centers responded. The hospitals included 25 university hospitals, 11 psychiatric hospitals, 6 children's hospitals, 4 health administration centers, and 1 health administration PET-CT center. Data regarding the number of scans performed for each of the 35 body regions are summarized in Table 1.

Table 1 Percent contributions of various CT categories to total number of procedures for 2007.

	Region of Body (%)				
Age Range	Head	Neck	Chest	Abdomen	Pelvis
0 - 3 month old	58	4	18	14	6
4 - 11 month old	56	5	13	17	9
1 - 4 year old	59	5	12	15	9
5 - 9 year old	55	5	10	18	12
10 - 15 year old	43	5	12	24	16
Adult	14	5	25	38	18

The number of CT procedures was closely correlated with the number of hospital beds. We used regression analysis to obtain the following model of the relationship between these two variables (see Fig. 1.)

$$y = ax^2 + bx + c \qquad (1)$$

where y is the number of CT procedures corresponding to the number of beds, x. This linear

quadratic model was well fitted with the estimated parameters listed in Table 2. Although we examined the relation of the number of CT procedures to other factors (e.g., the number of CT detectors, number of CT machines per facility, and the number of outpatients per day), no clear relations were found among these factors for prediction modeling. In addition, the number of CT procedures performed in psychiatric hospitals was less than the number predicted by the model. The preferred model was fitted to data excluding psychiatric hospitals. This handling of the data is justified because psychiatric CT procedures showed a different trend to those of other hospitals with a similar number of beds, having a very low number of CT procedures.

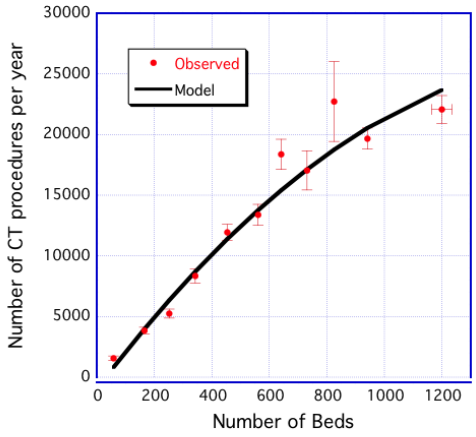

Fig.1. The relation between the number of annual CT procedures and the number of beds in hospital. The linear-quadratic model was well fitted to these data.

Table 2 Preferred model for the number of CT procedures as a function of the number of beds.

Year	a		b		c	
	Estimate	SE	Estimate	SE	Estimate	SE
2005	-0.00896	0.00206	31.294	2.076	-970.17	418.03
2006	-0.00822	0.0021	31.812	2.109	-988.039	424.76

*)The parameters listed show coefficients of a linear-quadratic model, y=ax^2 + bx + c.

Estimation

We used our model to estimate the total number of CT procedures performed in all the facilities in Japan. Calculations were conducted using the number of beds at each of approximately 8500 facilities that possess CT scanners, based on statistics from the Ministry of Health, Labor, and Welfare, Japan [14]. We estimated that approximately 20.5 million procedures were performed in 2005, and 21.2 million in 2006. In summation, estimates below zero, as calculated by the model, were considered to be zero. This approximation did not impart a substantial error to the final estimate. In contrast, regarding pediatric CT, the nationwide survey data did not provide a direct estimate because the number of procedures was too low to enable an accurate estimation using the model. Thus, the number of pediatric CT procedures was calculated by multiplying the total number of CT procedures by the fraction of pediatric cases (children aged 0–15 years) among the total number of CT procedures (approximately 3%) estimated in our survey. We estimated approximately 580,000 pediatric CT procedures in 2005 and 600,000 in 2006.

Comparison

The primary sources on the national use of medical service payment [15] and national surveys of medical facilities [14] have recently become available from the MHLW, according to laws regarding the disclosure of information. Using these sources, it is possible to estimate the annual number of total CT and pediatric CT procedures. Two sources from the Japanese Government contradicted each other until 1999 but are consistent recently. The estimate of 19.9-20.2 million in 2005 from the HMLW is in close agreement with the current estimate, 20.5 million, based on

the nationwide survey. In pediatric CT, the figure of approximately 0.6-0.7 million is also broadly consistent with the current estimate. The age-specific proportions in Table 3 also agree with this estimate and national statistics. Table 4 compares data among the UK, US., Sweden, and Japan. In Japan, no annual increase is seen for the UK, Sweden, and U.S. [2, 7, 11]. In addition, the number of procedures per capita for both total CT and pediatric CT is lower in Japan than in the U.S. The number of total CT procedures per thousand of population was 166 in Japan and 2007 in the U.S. The number of pediatric CT procedures per thousand of population was 32-34 in Japan and 76-94 in the U.S.

Table 3 Age-specific proportions of CT procedures in Japan.

Year	Present Study (%)	Statistics of Ministry of health, Labour and Welfare (%) *1		
Age Range	2007	2007	2006	2005
0 - 4 years old	1.13	0.58	0.77	1.15
5 - 9 years old	0.73	0.91	0.96	1.11
10 - 14 (15) years old	0.99 *2	1.14	1.22	1.19
Pediatric	2.85	2.63	2.95	3.45
> 15 (16) years old	97.15 *3	97.37	97.05	96.55

*1)Data from Ministry of Health, Labour and Welfare in Japan (2009a)
*2)This shows a number corresponding to 10-15 years old
*3)This shows a number corresponding to >16 years old

Table 4 Comparison of the numbers of total and pediatric CT procedures among the Sweden, UK, USA and Japan.

	year	Total population (million)	Pediatric Population 0-15 year old (million)	Total CT procedures (million)	Pediatric CT procedures (million)	CT procedures per 1000 people		Ref.
						Total	Pediatric	
Sweden	2005	9.05	1.64	0.65	0.017	71.8	10	*1
UK	2005	60.3	11.6	2.48	0.080	43.6	6.9	*2
	2006	60.6	11.5	2.73	0.088	49.5	7.6	*2
USA	2005	300	69.3	57.6	4.6 - 5.8	192	66 - 84	*3
	2006	299	66.0	62	5.0 - 6.2	207	76 - 94	*3
JAPAN	2005	128	18.8	20.5	0.58 - 0.71	162	31 - 38	*4
	2006	128	18.7	21.2	0.60 - 0.63	166	32 - 34	*4

1) Populations are based on the data:

Data from U.S. Census Bureau. http://www.census.gov/population/www/socdemo/age/
Data from National Institute of Population Social Security Research in Japan. http://www.ipss.go.jp

2) The numbers of CT procedures are estimated based on the data:
*1:Data from Number of radiological examination in Sweden 2005. Report from the Swedish Radiation Protection Authority SSI-2008:03(2008), in Swedish, Available on the website http://www.ssm.se
*2:Hospital Activity Statistics, Department of Health, UK,
http://www.performance.doh.gov.uk/hospitalactivity/data_requests/imaging_and_radiodiagnostics.htm
Regarding the pediatric CT, 2.7% of CT procedures was assumed to be undertaken.
*3:Data from NCRP. Ionizing Radiation Exposure of the United States. Bethesda, MD: National Council on Radiation Protection and Measurements; 2009: Report No 160 (NCRP 2009)
*4: The present study and Data from Ministry of Health, Labour and Welfare: Medical facilities in Japan (2009b)

Discussion

Repeat investigations and examinations in pediatric patients and during pregnancy must be given special consideration. Finally, a survey of the number of CT procedures performed will contribute to estimating the cancer risk from pediatric CT procedures and CT procedures in adults, and to investigating their significance in epidemiological terms. This study did not address the collective dose from CT in Japan. It may be better for radiological protection that the frequency of CT procedures and their typical doses should be separately informed to see the complete picture of the current status of the medical use of CT. Patient doses should be estimated on an individual basis to compare among CT examinations that are performed with the same purpose. To make easy clinical estimates in the field, the authors are developing a computational dosimetry system of organ doses according to different types of CT scans [16-18].

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