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The Nationwide Evaluation of X-Ray Trends, Part 2: US Trends for CT

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The use of CT for routine diagnostic imaging continues to grow, with modern CT equipment capable of providing an ever increasing array of features and tools to aid clinicians. One might even argue that it was the first truly digital diagnostic x-ray imaging modality because of the computational nature of producing a final set of tomographic images. Since its introduction into clinical practice in the early 1970s, CT has become the largest contributor to total collective effective dose in the United States from medical-related sources of radiation dose, with a rate of annual growth greater than 10% between 1983 and 2006 [1].

The FDA Center for Devices and Radiological Health conducted a survey of US hospitals in 1980, which showed that approximately 2.2 million CT examinations were performed in the United States during that year, with a rate of 1 CT examination per 100 members of the US population [2]. Of those CT examinations, 73% were of the head. A similar study of diagnostic radiologic procedures conducted in 1979 to 1980 found that 3.3 million CT procedures were performed annually, with the difference between that and the FDA study accounting for CT examinations conducted at sites other than hospitals [3].

After the introduction of CT into clinical practice, efforts were begun to understand and quantify the dosimetry of this new imaging modality. The FDA's Bureau of Radiological Health (as it was then known) needed a standardized method of dosimetry to include with its x-ray equipment testing programs. These programs, begun in 1974, tested x-ray installations for conformance to the new federal performance standards for diagnostic x-ray systems and their major components. Before the publication of federal performance standards for CT in 1985, a number of published studies investigated various methods to measure dose. McCullough and Payne [4] described a methodology using standard phantoms and thermoluminescent detectors. In 1981, Shope et al [5] introduced the computed tomography dose index. This methodology was subsequently incorporated into the federal performance standards for CT equipment [6].

Beginning in the early 1970s, the Nationwide Evaluation of X-Ray Trends (NEXT) program documented the general state of practice for diagnostic radiography. The early surveys revealed broad ranges in patient dose for a variety of commonly performed radiographic procedures. The NEXT program conducted a survey of CT in 1990, with additional surveys conducted in 2000 [7] and 2005 to 2006 [8]. We present selected findings from the two most recent surveys and highlight trends in clinical CT practice.

The 1990 NEXT survey of CT was limited to the capture of data for routine head scans, likely the most frequently performed CT examination at the time of the survey. Nearly every scanner surveyed was a single-slice system and scanned at a slice acquisition width of 10 mm. Although surveyed systems predominantly used high tube voltages, much as systems do today, the technology at the time limited scanning speed; the average and maximum gantry rotation times for a routine head scan were 4.2 and 13 seconds, and an average of 15 slices were acquired per examination. Eighty percent of the surveyed scanners were located at hospital sites.

Because of the rapid technological developments in CT that began during the late 1990s, the NEXT program conducted two additional CT surveys, in 2000 and 2005 to 2006. Helical and multislice scanning technologies were increasingly the standard technology for routine body CT examinations. During the 2000 survey, a majority of CT scanners at surveyed sites were helical-capable, single-slice systems. In the 2005 and 2006 survey, the majority of CT systems in use were helical-capable, multislice units. Half of surveyed CT scanners had multislice configurations of 8 slices or more, and 9% were 64-slice CT scanners. The majority of sites (79%) had CT systems equipped with tube current modulation (TCM) technology. Figure 1 summarizes the types of CT equipment surveyed.

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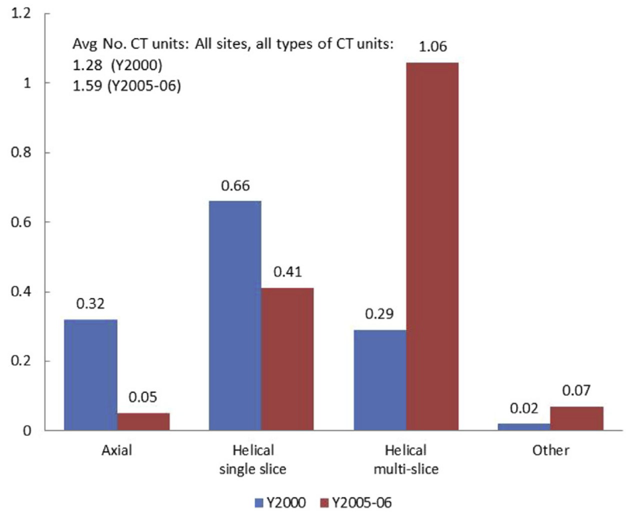

Fig 1. Distribution of CT equipment types for 2000 and 2005 to 2006 surveys.

When planning for the 2005 to 2006 survey began, it was recognized that CT scanners would be encountered that were equipped with TCM technology, a feature analogous to the automatic exposure control technology used in most radiographic systems. This technology can adjust the tube current (and hence tube current–time product) in various ways to account for the varying degree of patient attenuation in the scan field. This posed a significant survey challenge for the capture of dosimetric data. The 2000 NEXT survey did not seek out or encounter CT scanners equipped with TCM. In that survey, the standard 16-cm dosimetry phantom was used to capture dosimetric data. Inferences for dose from a broad range of body examinations were done using scanner protocols provided by surveyed facilities. The 2005 and 2006 survey sought to characterize the impact TCM had on patient dose during body examinations. A new phantom was developed specifically for such purpose. This new phantom was constructed of plastic (polymethylmethacrylate) and consisted of three adult body sections: chest, abdomen, and pelvis. Each section was designed to drive TCM in a way similar to that of an adult patient.

During the 2005 to 2006 survey, approximately 71% of surveyed CT scanners were equipped with TCM technology. Interestingly, for surveyed systems that used TCM, the survey documented somewhat higher values for mean tube current–time product for the routine abdominal and pelvic examination (254 mAs) compared with fixed–tube current scanning (217 mAs). A similar observation was made for nearly all adult body examinations. In fact, only the routine adult thoracic spinal examination was found to have a lower average scan tube current–time product for scanners using TCM compared with manual scanning. No assessment of image quality was made during the survey. TCM technology has matured since the 2005 to 2006 survey, and the findings would likely be different if this survey were conducted today.

Table 1. Summary tabulation of findings for selected CT examinations: NEXT 2000 and 2005 to 2006 surveys

	2000 NEXT Survey			2005-2006 NEXT Survey		
Examination	Facility Weekly Workload	$CTDI_{vol}$ (mGy)	Effective Dose (mSv)	Facility Weekly Workload	$CTDI_{vol}$ (mGy)	Effective Dose (mSv)
Adult head (brain and posterior fossa), axial scanning	27.6/27.0/222	63/33/161	2.1/1.1/90	43/46/188	69/32/159	2.6/1.2/148
Adult abdomen and pelvis*	29.3/26.2/137	17/9/83	13.7/7.1/37	37/44/224	20.5/12.0/177	15.9/9.1/161
Adult chest*	13.4/10.9/152	15/8/82	9.3/5.8/39	22/21/227	15/7/135	8.0/4.0/136
Child head				3/4/152	36/36/66	1.4/1.4/49
Child abdomen and pelvis				2.4/3.9/123	9/9/49†	13.0/25.6/36
Infant head				1/2/135	32/31/59	1.1/0.9/43
Infant abdomen and pelvis				0.7/1.7/105	14/9/36‡	7.1/6.2/20

Note: Data are expressed as mean/SD/number of observations. In the 2005 to 2006 survey, a child was specified as 5 to 6 years of age, and an infant was specified as 1 year of age or younger. $CTDI_{vol}$ = volumetric CT dose index; NEXT = Nationwide Evaluation of X-Ray Trends.
*Tabulated data for the 2000 survey represent only helical scanning; axial scanning was tabulated separately. Data for the 2005 to 2006 survey are for both helical and axial scanning, but axial scanning represents only 4% of surveyed sites for abdomen and pelvis and 3% of sites for adult chest.
†For the child abdominal and pelvic examination, $CTDI_{vol}$ is reported for the 32-cm body phantom.
‡For the infant abdominal and pelvic examination, $CTDI_{vol}$ is reported for the standard 16-cm CT phantom.

Table 2. Estimates for US total CT examination rates: 2000 and 2005 to 2006 surveys

	Hospitals		Sites Other Than Hospitals	
	2000	2005-2006	2000	2005-2006
Number of US sites with at least one CT unit	5,130	4,707	1,950	3,253
Estimated US number of CT examinations by facility type (millions)	39.8 (all)	63.9 (adult) 5.5 (pediatric)	5.4 (all)	11.7 (adult) 0.5 (pediatric)
Estimated total US annual number of CT examinations (millions)	45.1	81.6		

The 2005 and 2006 survey also captured data regarding a number of pediatric (child and infant) CT examinations. These data show that facilities on average used less radiation when scanning pediatric patients. For example, the average tube current—time product for a routine head scan was 174 mAs for a child and 158 mAs for an infant, compared with 332 mAs for an adult head (brain) examination. Similar results were observed for the routine abdominal and pelvic examination. Tabulations of selected findings for pediatric CT examinations are provided in Table 1.

Both NEXT CT surveys provide estimates for the total US annual CT examination workload (Table 2). These data show significant growth in the use of CT during the time period between the two surveys. For these estimates, data from the American Hospital Association's *AHA Guide* [9,10] were combined with survey data and state databases of registered clinical sites with CT equipment to estimate workloads for all US hospitals and sites other than hospitals with CT equipment. These estimates are outlined in detail in the respective report publications [7,8].

Will NEXT conduct a CT survey in the future? Recent efforts from the clinical imaging community to characterize patient dose in CT, such as the ACR's Dose Index Registry®, provide a much improved method for capturing and disseminating these data. NEXT can complement such remote data collection efforts with on-site capture of data items that are difficult to harvest remotely. Finally, NEXT continues to collaborate with professional partners such as the ACR and the American Association of Physicists in Medicine to ensure that future NEXT surveys address identified needs that the program is uniquely equipped to evaluate.

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