Original Article

TRENDS IN COMPUTED TOMAGRAPHY UTILIZATION RATES: A LONGITUDINAL PRACTICE-BASED STUDY

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Abstract

Objectives: Computed tomography (CT) use has increased dramatically over the past two decades, leading to increased radiation exposure at the population level. We assessed trends in CT use in a primary care (PC) population from 2000 to 2010.

Methods: Trends in CT use from 2000 to 2010 were assessed in an integrated, multi-specialty group practice. Administrative data were used to identify the impaneled primary care population and all CT imaging procedures. Utilization rates per 1,000-paneled patients and CT rates by type and medical specialty were calculated.

Results: Of 179,032 PC patients, 55,683 (31%) underwent CT. Mean age (SD) was 31.0 (23.6) years; 53% were female. In 2000, 178.5 CT scans per 1,000 impaneled PC patients were performed, increasing to 195.9 in 2010 (10% absolute increase, $p = 0.01$). Although utilization rates across the 10-year period remained stable, Emergency Department (ED) CT examinations rose from 41.1 per 1000 in 2000 to 74.4 per 1000 in 2010 (81% absolute increase, $p < 0.01$). CT abdomen accounted for over 50% of all CTs performed, followed by CT other (19%; included scans of the spine, extremities, neck and sinuses), CT chest (16%), and CT head (14%). Top diagnostic CT categories among those undergoing CT were abdominal pain, lower respiratory disease, and headache.

Conclusions: Although utilization rates across the 10-year period remained stable, CT use in the ED substantially increased. CT abdomen and CT chest were the two most common studies performed and are potential targets for interventions to improve the appropriateness of CT use.

Key Words: computed tomography, x-ray, utilization, primary care

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INTRODUCTION

The use of computed tomography (CT) has increased dramatically over the past two decades,[1] leading to increased radiation exposure at the population level. In 2007 more than 69 million CT exams were performed in the United States, and that number has increased nearly 10% annually.[2] It has been reported that 80 million CT scans are currently performed each year in the US.[3,4] It is estimated that CT examinations contribute up to 70% of the total radiation dose to the population.[5] This has led to increasing public health concern regarding the potential cancer risks associated with CT use.

Current risk estimates are derived largely from data on atomic bomb survivors who were exposed to low radiation doses that led to statistically significant increases in cancer risk.[6] An estimated 1.5 to 2 percent of all cancer diagnoses in the US may be attributable to CT use.[7] Epidemiological evidence has demonstrated an association between low-dose radiation exposure and the development of solid tumors.[8-11] Other data suggest comparable but lesser estimates from excessive radiation.[12] Although the risks for any one person are not large, the risk increases as additional studies are performed, highlighting the need to keep radiation doses as low as reasonably feasible when obtaining needed diagnostic information and to limit unnecessary CT use.

Last year, the Joint Commission issued a Sentinel Event Alert warning of the radiation risks of diagnostic imaging.[13] As pointed out in a recent article entitled *The No Outcome No Income Tsunami is Here*, the risk manager of the future must focus on anticipatory risk identification and mitigation systems. They must work closely with the quality teams to develop early recognition and warning initiatives that provide measurable high-reliability execution.[14] The modern risk manager must utilize appropriate initiatives like National Quality Forum (NQF) Safe Practice 4 (Risk Identification and Mitigation), which defines an entirely new collaborative role between risk and performance improvement groups.[15]

In the last few years, several studies have shown a substantial increase in CT imaging over time.[16,17] Most

of these studies have been conducted using cross-sectional survey data or longitudinal payer data which do not account for in-hospital imaging or the practice settings in which these patients are managed. We are aware of no published reports regarding trends in CT utilization in a primary care population in an integrated, multispecialty healthcare system or reports that highlight trends in CT use by physician specialty in both the inpatient and outpatient settings. The overall goal of this study was to track trends in CT use in order to identify targets for interventions to increase the appropriateness of CT use across our multispecialty health system. Specifically, we sought to: 1) investigate the trends in CT utilization in a primary care population over a 10-year period (2000-2010); 2) describe patterns of CT ordering by physician specialty; and 3) identify the leading types of CTs obtained and the associated diagnoses.

METHODS

Study Design and Setting

We conducted a retrospective study of all primary care patients from Mayo Clinic in Rochester, MN, a large integrated, multispecialty group practice. We focused on patients impaneled to primary care (Family Medicine, Community Internal Medicine, and Pediatrics; primary care impaneled patients are defined as those patients assigned to a specific primary care provider). This primary care practice serves local residents (from Olmsted and surrounding counties), Mayo Clinic employees, and their dependents.

Patient Selection

All pediatric and adult patients assigned to a primary care provider from January 1, 2000 to December 31, 2010 were included in the analysis. Patients who did not give consent for the use of their medical record were excluded from analysis in accordance with Minnesota state law. We assessed patterns of imaging in each year from 2000 to 2010.

Data Collection and Processing

Information was electronically abstracted from the electronic medical record (EMR) and administrative databases within Mayo Clinic's health records system. Mayo Clinic maintains all electronic medical record information within one system, including inpatient and outpatient clinic-visit information. No manual chart abstraction was performed.

Demographic variables collected included: date of birth, gender, and insurance status. Age was grouped into six categories of less than 18, 18 to 34, 35 to 49, 50 to 64, 65 to 79 and greater than 79. Insurance status was grouped into five categories Medicare, no insurance, other government (Medicaid and state programs), private/contract and unknown.

CT imaging procedures were extracted using standardized Current Procedural Terminology, Fourth Edition (CPT-4) codes. CT scans were organized by body region into four categories: "head," "chest," "abdominal," and "other." Abdominal CT included any CT of the abdomen as well as any CT of the abdomen and pelvis. Other CT included a variety of relatively uncommon scans examining the spine, extremities, neck and sinuses. Only CT scans performed on patients paneled to a primary care provider were included. In order to decrease the risk of overestimating utilization, we collapsed multiple procedures done on the same region on the same day into one CT. CT images performed on patients while they were not paneled were not included.

All physicians who ordered a CT examination for inpatient, outpatient, and emergency services from 2000 to 2010 were identified from the EMR. Physician specialties were categorized as cardiology, emergency medicine, gastroenterology, hematology, oncology, primary care, urology, and other. The principal diagnosis for each CT scan was obtained using diagnosis codes from administrative billing data. We used the Agency for Healthcare Research and Quality's Clinical Classification Software to organize the principal diagnoses into diagnostic categories.[18] Approval was obtained from the Mayo Clinic Institutional Review Board prior to conducting the study.

Statistical Analysis

Utilization rates per 1,000 impaneled patients were calculated for baseline characteristics. Overall utilization trends were examined by ordering physician patterns and anatomical scanning region and the frequency of common primary diagnosis by scanning region over the entire study period.

In addition to standard descriptive statistical methods, we performed linear regression analysis to assess for trends by study month in CT imaging (number of CTs per 1000 paneled patients). Analyses were conducted with the use of SAS software, version 9.1 (SAS Institute, Cary, NC). Statistical significance was set at .05 for modeling.

RESULTS

Our study population consisted of 179,032 patients who were impaneled to primary care between 2000 and 2010 (Table 1). Mean (±SD) age was 31.0 (±23.6) years, and 52.9% were female. A total of 228,121 CT scans were performed on 55,683 unique primary care impaneled patients (31.1 %) during the 10-year study period. Among those who had a CT scan obtained, there was a mean of 4.1±5.4 scans and a median of 2.0 scans per person (interquartile range, 1 to 5) over the 10-year study period. The proportion of paneled patients who underwent at least 1 CT increased with age, ranging from 13.6% in patients less than 18 years of age

to 65.5% in patients greater than 79 years. A slight higher percentage of females (32.3%) underwent CT scans compared to men (29.7%). The portion of paneled patients undergoing at least 1 CT was highest among the Medicare group.

Table 1: Number of Impaneled Patients undergoing a CT Scan, 2000 - 2010

	Total Population (N=179,032)	Patient having had at least 1 CT (N=55,683)	%
All	179,032	55,683	31%
Age Group			
<18	61588	8421	14%
18-34	41815	10530	25%
35-49	35332	13395	38%
50-64	21845	11121	51%
65-79	13146	8740	66%
>79	5306	3476	66%
Mean Age (SD)	31.0 (23.6)	44.3 (22.8)	-
Patient Gender			
Female	94759	30638	32%
Male	84273	25045	30%
Insurance Status			
Medicare	17980	12038	67%
No Insurance	5548	1462	26%
Other Government	18999	5048	27%
Private/ Contract	130239	36266	28%
Unknown	6266	869	14%

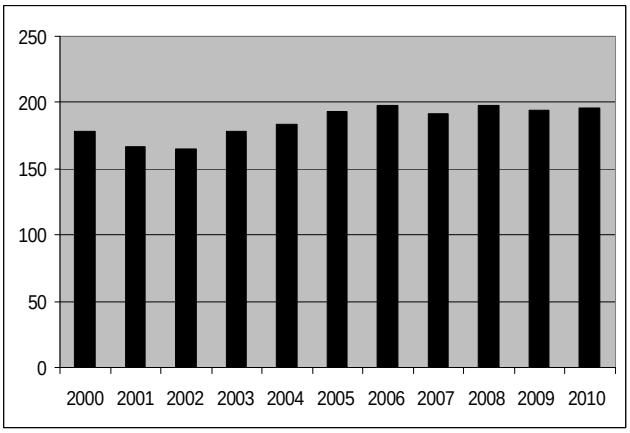

Figure 1. Utilization rates of all CT imaging per 1,000 paneled primary care patient, 2000 through 2010. The overall utilization rate increased from 178.5 CT scans per 1,000 in 2000 to 195.9 in 2010, a 10% absolute increase (p = 0.01 for trend).

Figure 1 displays the annual utilization rates of CT imaging among our paneled primary care population from 2000 to 2010. The annual utilization rate increased from 178.5 CT scans per 1,000 in 2000 to 195.9 in 2010, a 10% absolute increase ($p = 0.01$ for trend). Changes in CT imaging rates per 1,000 impaneled patients are shown in Table 2. The highest rate of increase in CT scans was in the >79 year-old age group, which increased by 41%, from 464.7 scans in 2000 to 645.5 in 2010 ($p < 0.01$ for trend). The utilization rates for Medicare were much higher than other insurance types and increased by 40% from 2000 to 2010 (439.9 to 615.8, respectively). Overall, the CT imaging rates were higher among females.

Table 3 reports CT utilization rates across study years by body region. Overall the proportion of scans was highest for CT Abdomen, accounting for nearly 50% of all scans. CT abdomen had the largest increase relative to other scan regions, rising from 83.8 per 1,000 paneled patients in 2000 to 104.8 in 2010 ($p < 0.01$ for trend).

The most frequently occurring diagnoses for CT by body region are listed in Table 4. Lower respiratory disease and chest pain accounted for 50% of the CT scans of the chest. Headache was the most frequent indication for CT head (26%). More than 30% of CT abdomen scans were for abdominal pain.

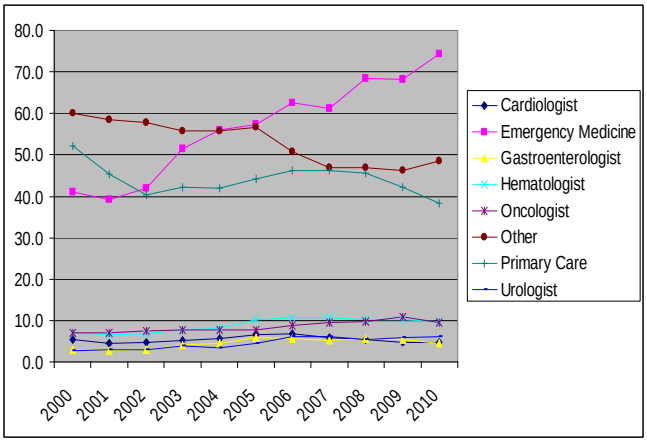

Figure 2. Utilization rates per 1,000 Paneled Primary Care patients for all CT imaging by ordering physician specialty from 2000 through 2010.

Figure 2 illustrates the overall utilization trends by ordering physician specialty.

There was a notable trend in the growth of CT imaging ordered by emergency medicine physicians. ED CT examinations rose from 41.1 in 2000 to 74.4 in 2010 (81% absolute increase, $p < 0.01$), while the ED patient volume remained stable. During the study period the mean age of patients undergoing CT in both our impaneled PC population and in those in the ED subgroup remained stable (Appendix 1). By comparison, the CT rate among primary care physicians decreased from 52.1 in 2000 to 38.3 in 2010 ($p < 0.01$ for trend).

Table 5 reports the number of patients per year who had received one, two, three and four or more CT scans. Those receiving 4 or more scans in one year increased from 9.6 per 1,000 paneled patients in 2000 to 13.2 in 2010 ($p < 0.01$ for trend).

DISCUSSION

Main study findings

The overall goal of this study was to track trends in CT use across an integrated multispecialty health system in order to identify targets for interventions to increase the appropriateness of CT use. Though the utilization rates across the 10-year period remained relatively stable, CT use in the ED increased by over 80% and was accompanied by a decrease in CT use by primary care physicians. CT abdomen was the most frequently evaluated region of the body and accounted for over 50% of all CT scans performed, followed by CT other (scans of the spine, extremities, neck, and sinuses), CT chest, and CT head. The highest rate of CT scanning was observed in patients over 79 years of age, and the top indications for CT were abdominal pain, lung disease, and headache.

The increasing use of CT scans involves many medical specialties, of which the ED is an important contributor. Over the study period we observed a marked increase in the ordering of CT scans by emergency medicine physicians. During this period, ED visits remained stable, whereas the proportion of CT scans ordered increased by 81 percent. Although one might postulate that, as the population ages, patients cared for in the PC and ED settings are increasing in age, potentially explaining the increasing rate of CT utilization. However, the mean age of patients undergoing CT in both the PC and ED settings remained stable during the study period.

Given the large number of patients in the U.S. being treated annually in EDs, this finding has enormous implications for the general population.[19] Our results build on prior studies that suggest CT use in the ED may be increasing sharply relative to its use in other clinical settings.[20-24] Some factors that may have contributed to this increase in CT scans ordered by emergency physicians are that CT scans may be more sensitive for detecting serious injuries, the speed and timeliness to obtain critical diagnosistic information, increased availability of CT scanners and concern about malpractice lawsuits for a missed diagnosis.[25]

CT Abdomen and CT Head are two of the most commonly performed studies in the ED. Our detailed analyses of diagnosis by CT body region found that abdominal pain and kidney stones were the most frequent diagnosis in CT Abdomen scans. We found that the most common diagnosis in CT Head was headache. The frequent use of CT for the diagnosis of common conditions such as kidney stones and headaches has been questioned in the literature.[26-28] This analysis suggests that the utilization of CT Abdomen and CT Head in the ED are potential opportunities to investigate strategies for quality improvement. Several strategies have been introduced in efforts to guide the appropriate use of CTs.[29] Numerous decision rules have been developed for specific patient conditions such as minor head trauma, pulmonary embolism and cervical spine injuries in an effort to avoid potential over-utilization of CT scans.[29-32]

Our finding that some of our patients had more than 4 CT scans per year is illustrative of the potential for significant radiation accumulation over time. Exposure to even moderate degrees of medical radiation presents an important yet potentially avoidable public health threat.[7] This underscores the need to ensure providers and patients are informed about the risks of radiation and making sure exposure is as low as reasonably achievable without sacrificing quality of care.[33] In a 2004 survey of radiologists and emergency-room physicians,[34] approximately 75% of the group significantly underestimated the radiation dose from a CT scan and only 9% of emergency-room physicians believed that CT scans increased the risk of cancer. To date there have been recent efforts focusing on raising awareness among providers about the potential risk of cumulative radiation dose.[35]

Comparison with other published studies

A previous study focused on increases in use of medical imaging using payer data and focusing on overall imaging use in a large integrated health system.[17] In this study, the use of CT imaging increased from 81 per 1,000 enrollees to 181 per 1,000 enrollees between 1997-2006. Similarly, use of outpatient CT imaging among Medicare beneficiaries increased from 138 per 1,000 beneficiaries to 292 per 1,000 beneficiaries between 1998 and 2008, respectively.[36] Our analysis extends this work by specifically examining CT use across inpatient and outpatient settings and CT use by ordering physician specialty. As such, our finding that CT use has been increasing in ED is of considerable interest.

Future Directions

With greater knowledge of CT utilization in our PC population, providers and organizations may be motivated to create strategies for the appropriate use of CT scans. At Mayo Clinic, radiologists are now tracking radiation exposure in order to better identify those patients who have had multiple CT scans. This is the first step to effectively work together with the ordering physician and patients to reduce radiation exposure and ensure that the most appropriate procedure is ordered. Deployment of validated clinical decision support to assist physicians in choosing the most appropriate imaging study for the patient, is a promising area of further investigation and has potential to decrease unnecessary radiation exposure. The ED practice is a logical environment for implementation and study of

computerized clinical support tools in light of the significant increase in CT utilization in the ED.

Limitations

Our investigation has several potential limitations. Our data represent utilization from one health system, thus the extent to which our findings can be generalized to other populations is unknown. It is also likely that our imaging rates are biased upwards somewhat since the payer-based data included individuals who did not seek health care or present to the health care system, and the denominator only included patients impaneled in primary care. Our cohort only included patients impaneled to a primary care provider and excluded patients who did not have an assigned primary care provider. However, one might anticipate that patients presenting to the ED without an assigned primary care provider might have an even higher rate of CT utilization than that observed in this investigation, as these patients have no established mechanism to ensure outpatient follow-up. Moreover, our data represent CT utilization in both the inpatient and outpatient setting in a multispecialty health system and thus provide a unique contribution to the existing literature. There is potential for overestimating the number of CTs when CTs were obtained on multiple body regions on the same day. To decrease the risk of overestimating utilization, we collapsed multiple procedures done on the same region on the same day and counted it as one CT. Finally, our study did not address the appropriateness of CT use. We plan to conduct future investigations that assess the appropriateness of CT use and to measure the effect of interventions with demonstrated efficacy on the diagnostic yield of imaging**.**

CONCLUSIONS

CT utilization in this PC population remained relatively stable over the study period. However, the number of CT scans ordered by ED physicians increased substantially. Abdominal CT was the most common type of CT performed, followed by CT of other areas such as chest and head.

NQF Practice 1, entitled "Leadership Structures and Systems," suggests that leadership structures and systems should be established in hospitals to ensure that there is organization-wide awareness of patient safety performance gaps, direct accountability of leaders for those gaps, and adequate investment in performance improvement abilities, and that actions are taken to ensure safe care of every patient served.[15]

These data obtained from all PC inpatients and outpatients in an integrated multispecialty health system identify opportunities for further improving CT utilization and Safe Practice 1 implies that investment could be made in further improvements to reduce radiation exposure. Consideration of alternative nonionizing studies and implementing evidence-based decision support – particularly in the ED setting for patients with abdominal pain and headache – are promising approaches for future interventions to decrease radiation exposure, in patients being considered for CT.

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Table 2: CT Utilization rates per 1,000 Paneled Primary Care Patients between 2000 and 2010

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	p-value
ALL	178.5	166.9	164.9	177.9	183.3	193.3	197.7	191.7	197.3	193.9	195.9	0.01
Age group												
<18	52.8	46.2	45.2	45.4	39.6	43.4	42.9	39.5	36.2	35.2	30.4	<0.01
18-34	124.5	118.8	116.1	131.9	123.9	126.3	128.1	115.8	124.4	123.2	120.9	0.87
35-49	167.2	160.6	159.2	179.5	187.2	196.3	194.5	184.3	198.1	201.1	196.3	<0.01
50-64	252.1	244.0	243.3	273.0	278.4	287.1	294.7	292.6	281.6	270.3	282.1	0.01
65-79	401.7	390.5	411.4	447.7	485.3	524.5	517.1	516.7	529.2	507.5	494.9	<0.01
>79	464.7	473.8	492.3	493.4	571.9	611.0	635.2	632.3	644.2	606.1	645.5	<0.01
Sex												
Female	176.4	171.0	165.0	186.1	191.8	196.9	207.0	198.6	203.0	198.5	202.7	<0.01
Male	181.1	161.8	164.8	168.6	173.6	189.2	187.2	183.9	190.7	188.7	188.2	0.08
Insurance Status												
Medicare	439.9	451.5	483.4	521.7	583.5	633.1	628.2	639.4	653.9	613.1	615.8	<0.01
No Insurance	211.6	244.2	213.0	247.4	235.6	192.0	174.4	175.3	206.0	198.3	216.9	0.31
Other Government	172.8	164.3	193.6	219.8	272.1	263.2	284.5	268.6	265.8	284.9	270.6	<0.01
Private/Contract	125.4	128.6	135.3	155.0	160.1	171.4	169.3	163.2	163.0	155.3	156.5	0.08
Unknown	0.0	0.4	0.0	0.3	0.2	0.1	2.0	1.0	1.1	1.0	0.8	<0.01

Table 3: Number of CT Scans performed (per 1,000 paneled patients) By Scan Region

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	p-value
ALL	178.5	166.9	164.9	177.9	183.3	193.3	197.7	191.7	197.3	193.9	195.9	0.01
Image/Scan Region												
CT Abdomen	83.82	79.1	79.28	85.73	89.6	93.87	105.28	101.38	107.03	104.12	104.8	<0.01
CT Chest	28.39	27.22	27.88	30.29	29.34	30.41	33.491	32.248	31.537	32.205	30.66	<0.01
CT Head	23.22	20.9	18.94	17.1	19.1	28.34	28.811	28.164	29.68	28.791	28.74	<0.01
CT Other	43.02	39.63	38.84	44.82	45.29	40.66	30.139	29.867	29.022	28.776	31.71	<0.01

Table 4. Top 5 Diagnostic Categories of CT scans by body region, 2000-2010

CT Abdomen/Pelvis	**N**	**%**
Abdominal pain	33268	31
Calculus of urinary tract	8571	8
Genitourinary symptoms and ill-defined conditions	4184	4
Non-Hodgkins lymphoma	3894	4
Other and unspecified gastrointestinal disorders	3360	3
CT Head	**N**	**%**
Other headache	6000	26
Acute cerebrovascular disease	2133	9
Conditions associated with dizziness or vertigo	1708	7
Other nervous system symptoms and disorders	1440	6
Other intracranial injury	1267	5
CT Chest	**N**	**%**
Other and unspecified lower respiratory disease	12038	38
Nonspecific chest pain	3854	12
Non-Hodgkins lymphoma	1781	6
Pulmonary heart disease	863	3
Pleurisy; pleural effusion	751	2
CT Other	**N**	**%**
Spondylosis; intervertebral disc disorders; other back problems	4729	12
Fractures	4681	12
Respiratory infections	4105	10
Other upper respiratory disease	2835	7
Other injuries and conditions due to external causes	2107	5

Table 5: Number Patients (per 1,000 paneled patients) by number of scans, 2000-2010

Number of CT Scans	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**p-value**
1	43.9	42.6	37.5	37.6	35.5	32.7	38.0	36.8	36.6	35.8	34.9	0.02
2	28.3	26.9	26.5	28.3	28.4	31.4	30.6	29.3	29.8	29.2	29.7	0.01
3	7.2	6.4	6.6	6.8	7.1	8.2	7.8	7.4	7.6	7.5	7.2	0.01
4+	9.6	9.0	9.5	10.9	11.8	12.3	12.5	12.2	13.2	12.8	13.2	<0.01

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Appendix 1. Mean age of the primary care (PC) impaneled population, of PC impaneled patients who underwent computed tomography (CT), and in those who underwent CT in the Emergency Department (ED) by year.

YEAR		Mean age	
	PC population	PC CT population	ED CT population
2000	36	54	52
2001	35	54	51
2002	35	54	51
2003	35	52	49
2004	35	54	50
2005	35	54	49
2006	35	54	50
2007	35	55	51
2008	36	55	51
2009	36	55	51
2010	36	56	53

