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Increasing utilization of computed tomography in the adult emergency department, 2000–2005

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Abstract This study aims to characterize changes in computed tomography (CT) utilization in the adult emergency department (ED) over a 5-year period. CT scans ordered on adult ED patients from July 2000 to July 2005 were analyzed in five groups: head, cervical spine, chest, abdomen, and miscellaneous. ED patient volume and triage acuity scores were determined. Triage acuity scores are used to determine the severity of a patient's illness or injury and the need for immediate evaluation and treatment. There were 46,553 CT scans performed on 27,625 adult patients in the ED during the study period. During this same period, 194,622 adult patients were evaluated in the ED. From 2000 to 2005, the adult emergency department patient volume increased by 13% while triage acuity remained stable. During this same period, head CT increased by 51%, cervical spine CT by 463%, chest CT by 226%, abdominal CT by 72%, and miscellaneous CT by 132%. Although increases were generally greater for patients over age 40, the increase in those less than 40 years was also substantial. Of the 4,320 individual patients who underwent chest CT, 83 (2%) had chest CT on three or more separate ED visits. Of 10,960 patients undergoing abdominal CT, 406 (4%) had abdominal CT on three or more separate ED visits. ED CT utilization has increased at a rate far exceeding the growth in ED patient volume. This presumably reflects the improved utility of CT in diagnosing serious pathology, its increased availability, and a desire on the part of physicians for diagnostic

certainty. Whether this increase in utilization results in improved patient outcomes is at present unclear and deserves additional study.

Keywords Computed tomography · Utilization · Emergency treatment · Process assessment

Introduction

Computed tomography (CT) has become the single most important diagnostic modality in the emergency department (ED) with efficacy in both traumatic and non-traumatic conditions. It also represents a potentially large radiation exposure for patients and a source of significant cost in healthcare. Previous studies looking at aggregate data (i.e., all CT) or a few indications have shown an increase in the use of CT in the ED, but the extent of this increase and its relation to type of study and age of patient have not been fully investigated [1–3]. Although much has been written addressing CT utilization in pediatrics, in this study we seek to gain a better understanding of CT utilization patterns in the adult ED [4–6]. Such information is necessary to identify potential areas of over-utilization and to target areas for research in clinical decision rule development.

Materials and methods

We analyzed the radiology database at a tertiary care medical center, identifying CT scans performed on adult (age ≥ 18 years) ED patients from July 1, 2000 to June 30, 2005. CT scans were organized by body region into five groups: “head,” “cervical spine,” “chest,” “abdomen”, and “miscellaneous.” Abdominal CT included any CT of the abdomen as well as any CT of the abdomen and pelvis. Miscellaneous CT included a variety of relatively uncommon scans examining the extremities, thoracic or lumbar spine, soft tissue of the neck, sinuses, and face scans. CT scan data was also stratified by age of patient into two groups: ≤ 40 years of age and >40 years of age.

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An ED database was analyzed to determine the total number of patient encounters during the same period. We then compared the rate of growth of CT scan utilization to growth in emergency department patient volume. The emergency department database was also searched for triage acuity levels to examine potential changes in patient disease or injury severity over this time period. Triage acuity scores are standardized scores assigned by the triage nurse to determine the severity of a patient's illness or injury and the need for immediate evaluation and treatment. The Emergency Severity Index version 3, used in our center, has been validated and shown to have excellent inter-rater reliability. In addition, it correlates well with patient outcomes such as admission, level of care (e.g., telemetry and ICU) and mortality [7]. We used triage acuity as a marker of potential changes in the acuity of the emergency department population during the study period, which might influence CT utilization.

Utilizing the radiology database, we also determined the number of patients who had received multiple CT scans of the chest or abdomen on different ED visits during the 5-year time period. This data was also analyzed by patient age and sex.

The university institutional review board approved this study.

Results

A total of 46,553 CT scans were ordered from and performed on 27,625 adult patients in the ED during the study period. Demographic data by group are shown in Table 1. Numerical data by CT group and year are shown in Fig. 1. The percentage increase in CT group compared with ED volume is shown in Fig. 2. During this period, the total number of patients undergoing head CT increased by 51%, cervical spine CT by 463%, chest CT by 226%, abdominal CT by 72%, and miscellaneous CT by 132%. This increase occurred in both patients older and younger than 40 (Table 2). The rates of increase for cervical spine CT and chest CT were greater in younger patients, while the rate of increase was greater in patients older than 40 for head, abdominal, and miscellaneous CT.

During this same period, a total of 194,622 adult patient visits were logged in the ED. Adult ED patients undergoing CT had a mean age of 49.7 and a male to female ratio of 1.1:1. From July 1, 2000 to June 30, 2005, ED patient volume increased by 13%. The percentage of all ED eval-

Table 1 Demographic data by CT type

Type of CT	Mean age (SD)	Patient ratio (male to female)
Head	54.3 (21.6)	0.95:1
Cervical spine	46.8 (21.7)	1.6:1
Chest	53.2 (18.4)	0.97:1
Abdomen	45.8 (18.0)	1.02:1
Miscellaneous	42.7 (18.7)	1.7:1

uations that led to patients undergoing CT is displayed by CT group in Fig. 3. By the last year of the study period, 13% of patients presenting to the ED underwent head CT, 4% underwent cervical-spine CT, 4% underwent chest CT, 8% underwent abdominal CT, and 2% underwent miscellaneous CT. Note that the data regarding percent of evaluations that involved CT are not simply additive as many evaluations (particularly in trauma patients) led to several different CTs (e.g., head, cervical spine, chest, and abdomen) on the same ED visit.

A total of 4,320 individual patients underwent CT of the chest and 10,960 patients underwent CT of the abdomen and pelvis during one or more ED visits in the study period. Eighty-three (2%) of these patients underwent chest CT on three or more occasions with 406 (4%) undergoing abdominal CT on three or more ED visits. The median ages of the patients undergoing three or more chest or abdominal CT (at the time of their last scan) were 54 years [standard deviation (SD)=14] for chest CT and 44 years (SD=15) for abdominal CT. One patient had undergone 18 noncontrast abdominal CTs performed during separate ED visits over the 5-year study period.

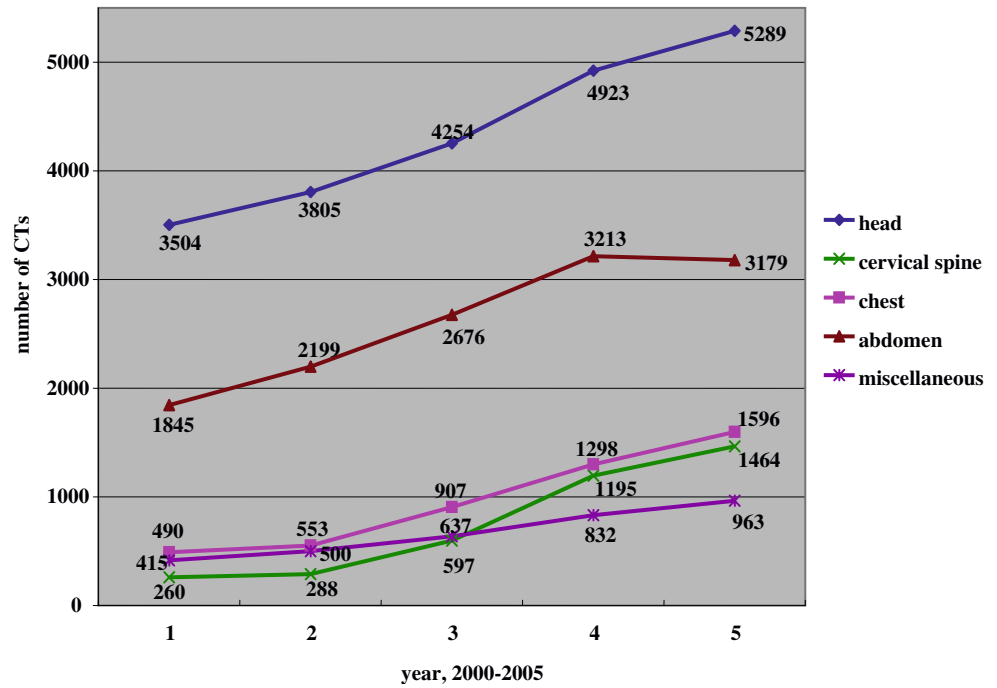
The distribution of triage acuity scores remained relatively stable during the study period consistent with no major shift in the type of patients seen during the study period.

Discussion

CT has become the essential diagnostic imaging modality in the ED setting. It is the standard of care for the evaluation of trauma, suspected appendicitis, diverticulitis, and severe pancreatitis. CT has replaced intravenous urography (IVU) for suspected renal colic, nuclear medicine for the evaluation of pulmonary embolus, and angiography for evaluation of major vascular structures. Some have labeled CT indeed "the physical examination of the 21st century" [8]. At the end of the last decade, CT scans at one academic medical center accounted for 11% of all radiology procedures and gave 67% of the effective radiation dose from all diagnostic radiology [9].

With this growing list of indications comes the growing concern regarding potential overuse resulting in unnecessary radiation exposure and expense. The individual dose from a single CT study is relatively low, in the range of 10 mSv, but will vary depending on site(s) scanned and scan protocol (slice thickness, milliamperes second, kilovolt, and exposure control) [10–12]. Although there has been debate regarding potential carcinogenesis from doses below 100 mSv, the linear no threshold model for radiation effects is most commonly accepted and is endorsed by the National Research Council in their BEIR VII report [13]. In this model, approximately 1 in 1,000 persons would develop cancer from an exposure to 10 mSv over a 70-year lifetime. This compares to approximately 420 people per 1,000 expected to develop cancer unrelated to radiation exposure [13]. The concern for radiation carcinogenesis, however, is amplified when particularly radiosensitive organs are

Fig. 1 CT utilization in the ED by CT type



included in the exposed field (e.g. breast, lung, and thyroid), when multiple CTs are undertaken, or when a younger population is scanned [5, 6, 14]. Although it is well known that radiation sensitivity is substantially greater in the pediatric population, it is less often appreciated that such increased sensitivity does not abruptly end at age 18 but rather only reaches the adult plateau in the fourth decade and then continues to decline slowly thereafter [5]. Because of

the low but real risk associated with CT, much recent work has been done to decrease dose by judicious or automatic adjustment of exposure factors depending on patient age and size [5, 11, 15–18]. Other authors have emphasized the importance of decreasing unnecessary exams [4]. The US Food and Drug Administration has published recommendations both for optimizing CT settings and reducing unnecessary scans [19].

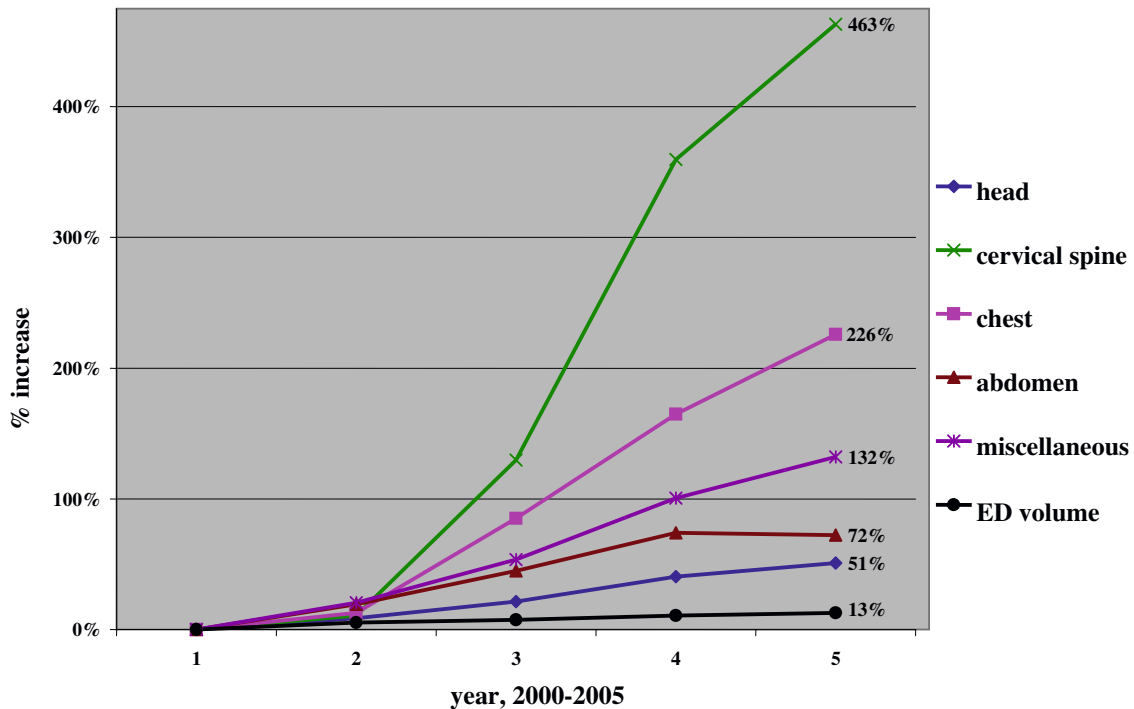


Fig. 2 Increase in CT utilization by CT type, compared with ED volume

Table 2 Percent increase in CT utilization in the ED 2000–2005 by patient age

Type of CT	Percentage (%) of increase, patient age ≤40	Percentage (%) of increase, patient age >40
Head	42.3	54.9
Cervical spine	496.6	435.7
Chest	318.3	199.2
Abdomen	62.9	79.8
Miscellaneous	110.8	161.1

Along with radiation risk, CT also comes with an economic price. Although the charges are small when compared with the cost of operation or hospitalization, they are not trivial with insurance reimbursement ranging from around US\$400 for cervical spine CT to US\$1,400 for CT of the abdomen and pelvis. The expenditures on equipment are also important. It has been projected that well over US \$5 billion dollars will have been spent on CT equipment from 2000 to 2005 [20].

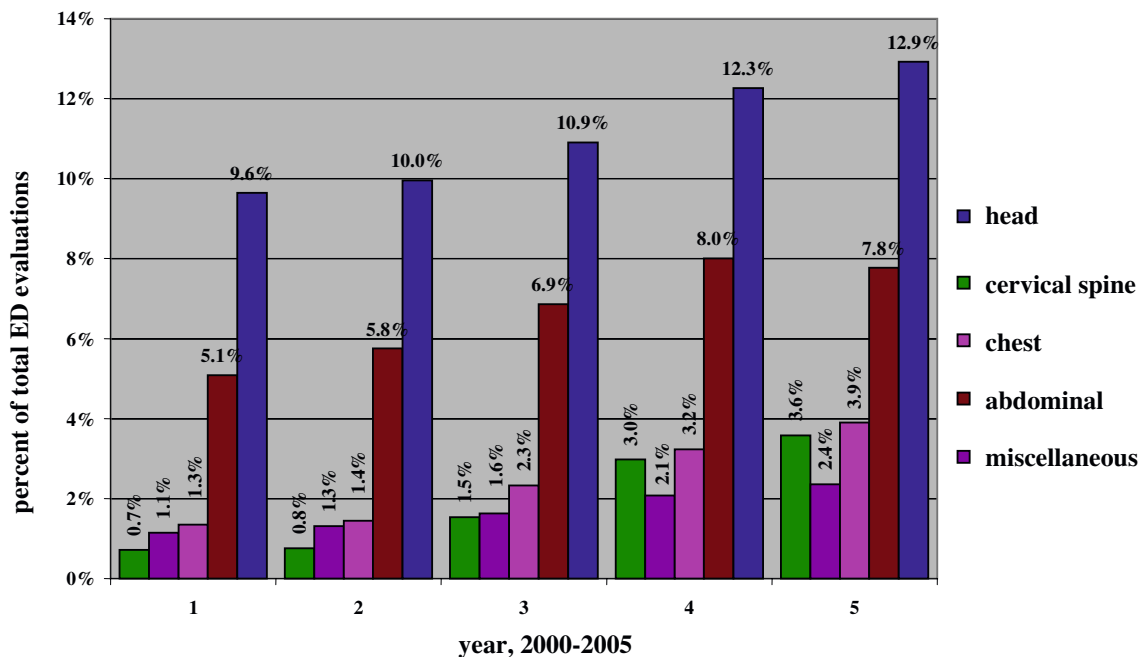
Given these twin concerns of expense and radiation exposure, we undertook this study to gain a better understanding of the present CT utilization and rate of change of CT utilization in our ED setting over the past 5 years. We chose the ED to gauge utilization of CT in a purely diagnostic setting rather than its overall use. We felt the latter would be more difficult to interpret with the larger variety of indications including particularly protocol-driven tumor follow-up. The ED is also a crucial part of the health care delivery system nationwide with an estimated 114 million yearly visits or approximately 40 visits per 100 persons per

year (2003 data) [21]. A previous study, looking at only Medicare patients in the ED and examining only CT in the aggregate, did show substantial annual growth rates averaging 23% a year from 1998 through 2002 [1].

Our data confirm that CT use has grown dramatically over the past 5 years. Although the rate of increase varies with the particular body region imaged, all regions show an increase much greater than the growth in patient volume over the same time period. Furthermore, this increase has occurred in both younger and older adults. The rate of increase in chest CT is of note as it was substantially greater in the younger adult population. This is of particular concern given the radiation sensitivity of breast and lung tissue.

The reasons for this increase, we believe, are multiple. First, with the introduction of helical followed by multislice scanners, there has been a major increase in diagnostic indications for CT. Cervical spine CT, for example, has replaced plain films in the high risk setting. This is probably primarily responsible for the nearly 500% increase noted in this study. CT angiography has replaced catheter angiography in the evaluation of aortic dissection and transection and replaced the ventilation/perfusion (V/Q) scan in the evaluation of pulmonary embolus, driving up the numbers of chest CTs. Noncontrast CT has replaced the traditional IVU in the evaluation of renal colic. CT use in the diagnosis of appendicitis, diverticulitis, and pancreatitis, although introduced earlier, has now become ubiquitous.

In many cases, however, the CT volume for a particular study exceeds the volume of the study it is replacing. For example, studies have shown that we are now evaluating more patients for renal colic by CT than we ever did by IVP, and far more for pulmonary emboli by CT angi-

**Fig. 3** Percentage of ED evaluations involving CT by CT type

ography than we did by V/Q or catheter-based pulmonary angiogram [2, 22, 23]. Head CT has also increased in the past 5 years without a significant change in diagnostic indication. This suggests that other factors have also become important in driving increased CT utilization.

The increased availability and speed of CT scanning is likely one of the factors in growing ED CT utilization. CT scanning is now available on a 24/7 basis, is frequently located adjoining the ED, and often requires less than ten minutes to perform. Interpretation is similarly rapid with either an in-house radiologist or resident or a similarly rapid “nighthawk” service available. Because of this rapid turn-around time, radiographic studies are often done as part of an initial evaluation rather than as a result of that evaluation. It is not uncommon for radiographic results to be available before basic laboratory values and, in some cases, even before a complete history and physical examination are performed. Ease of obtaining studies has also lowered the threshold for “bundling” studies that may not have been ordered in the past (e.g., a cervical spine CT with any trauma patient requiring a head CT or vice versa).

Beyond the technical factors and availability discussed above, we suspect there has also been a change in the tolerance for diagnostic uncertainty on the part of ED physicians, their consulting colleagues, and their patients. “Tincture of time” has become an unacceptable part of many diagnostic work-ups. The patients often want to know “now” what they have or be reassured that their scan is negative. Consulting physicians (e.g., surgeons or urologists) often want a CT before evaluating a patient. Admitting teams want a diagnosis to determine the appropriate placement before accepting an admission. ED physicians are hence under considerable pressure to arrive at a confident diagnosis rapidly.

An additional factor that may also increase CT utilization is the lack of physician knowledge of radiation exposure considerations. A survey of physicians at two UK hospitals showed that 97% underestimated the radiation dose of common radiologic examinations including CT [24]. A survey of ED physicians at a US academic medical center showed only 9% believed that CT increased the risk of cancer. Although radiologists scored somewhat better (47% believed that CT increased the risk of cancer), the dose estimate for a single CT scan of the abdomen and pelvis was underestimated by approximately three quarters of both ED physicians and radiologists [25].

Whatever combination of factors is responsible for the increase in CT utilization in the ED, the increase should ultimately be justified by improving health outcomes. Despite often compelling evidence of the accuracy of CT in arriving at a diagnosis, it cannot be taken as a given that any increase in its use will be advantageous. For example, additional scans may reflect simply a lessening of clinical acumen or a lowering of acceptable pre-test probability. In this situation, the increased use of CT finds no new actionable disease, produces only more normal results, and adds radiation and expense burden to the population. It has been suggested that this scenario is operative in the ED evaluation of pulmonary embolus. A study comparing ED

patients evaluated for pulmonary embolus in 1997–1998 with those evaluated in 2002–2003 found a 430% increase in patients evaluated for embolus by CT pulmonary angiography (from 81 to 349). This increase in CT utilization, however, found no more cases of pulmonary embolus than in the earlier time period and, in fact, found two less (22 positives in 1997–1998 and 20 positives in 2002–2003) [2]. Similar increases in ED CT utilization accompanied by a decrease in the rate of positive findings has been noted for facial and cervical spine CT [3].

CT use may also alternatively fail to affect clinical outcome because the information being provided, although accurate, is not crucial to clinical management. In a study comparing ED patients being evaluated for suspected urinary tract calculi in 1997 (before renal colic CT was introduced) with 1999 (after renal colic CT was introduced), a 27% increase in imaging studies per patient visit was noted. This coincided with a 95% decrease in IVP use and a tenfold increase in CT use. In spite of this increase, there was no change in health outcomes as measured by rates of initial or subsequent hospital admission, length of initial hospitalization, return visits to the ED, or frequency of subsequent hospitalization for abdominal symptoms. It is interesting to note that there was also no difference in the length of stay in the ED [22].

Although work on developing clinical decision rules to govern radiology utilization in the ED setting has been done in specific areas (e.g., cervical spine fractures and pulmonary embolus) [26–29], it is suggested, based on the across-the-board increases in CT utilization documented here, that much work remains. Prospective studies looking at appropriate utilization of CT could yield potential benefit in both economic savings and reduced radiation exposure.

It is interesting that approximately 2–4% of the patients undergoing either chest or abdominal CT had had two or more prior CTs of the same body region on earlier ED visits. The age of the patients undergoing multiple CTs in combination with the possibility that these patients may have undergone additional CTs as inpatients or at other medical centers raises concern regarding cumulative radiation dose. The reasons driving the multiple studies are unclear. The results from earlier studies should have been easily accessible in the ED either on our picture archiving and communication system or on our computerized medical record system. The lack of continuity of clinical care in the ED may be partly responsible as may be the other factors discussed previously.

Although our data show substantial increases over the past 5 years, it is unclear what the future holds. Only abdominal CT showed evidence of leveling off in the last 2 years of our study period. This fact may reflect the relative maturity of many of the indications for abdominal CT. Substantial increases in chest CT may, however, be seen in the near future if new indications for cardiac CT, particularly CT coronary angiography, are adopted [30].

Certain caveats should be considered when evaluating our data. First, it is possible that the changes in disease prevalence presenting at our ED may have led to some of the changes in CT utilization noted during this time

interval. We think this unlikely both from anecdotal experience and based on the relative stability of triage acuity scores during the study period. Second, changes in staff may have affected CT utilization more than the change in the ordering pattern of existing staff. We think this is also unlikely as the majority of our ED faculty including the chairperson have been the same during this time interval. Third, our data, having come from a university hospital, may not be applicable to a community hospital setting. Although this may be true, we believe that the changes seen in our setting likely foreshadow similar changes to come in the community. In a nationwide survey in 2003, for example, CT or magnetic resonance imaging was already noted to be used in 8% of overall ED visits [21]. Lastly, it is important to note that our data do not allow us to evaluate the true benefit or harm of CT in our study population. It may be that each patient undergoing CT in this study had significant pretest probability of disease that warranted imaging. We cannot determine from our data whether the aggressive use of CT was superfluous or beneficial by reducing observation time, admissions, or unnecessary procedures. This study, however, acts as a cautionary flag suggesting that further work needs to be done.

In summary, CT utilization has increased dramatically in the ED over the past 5 years in both younger and older adults. Whether this increase has resulted in improved health outcomes or unnecessary expense and radiation is unclear and awaits additional research.

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