Effect of Emergency Department CT on Neuroimaging Case Volume and Positive Scan Rates

Kader Karl Oguz, MD, David M. Yousem, MD, Tom Deluca, Edward H. Herskovits, MD, PhD, Norman J. Beauchamp, MD, MHS

Rationale and Objectives. The authors performed this study to determine the effect a computed tomographic (CT) scanner in the emergency department (ED) has on neuroimaging case volume and positive scan rates.

Materials and Methods. The total numbers of ED visits and neuroradiology CT scans requested from the ED were recorded for 1998 and 2000, the years before and after the installation of a CT unit in the ED. For each examination type (brain, face, cervical spine), studies were graded for major findings (those that affected patient care), minor findings, and normal findings. The CT utilization rates and positive study rates were compared for each type of study performed for both years.

Results. There was a statistically significant increase in the utilization rate after installation of the CT unit (P < .001). The fractions of studies with major findings, minor findings, and normal findings changed significantly after installation of the CT unit for facial examinations (P = .002) but not for brain (P = .12) or cervical spine (P = .24) examinations. In all types of studies, the percentage of normal examinations increased. In toto, there was a significant decrease in the positive scan rate after installation of the CT scanner (P = .004).

Conclusion. After installation of a CT scanner in the ED, there was increased utilization and a decreased rate of positive neuroradiologic examinations, the latter primarily due to lower positive rates for facial CT scans.

Key Words. Brain, CT; emergency medical service system.

The factors that lead to the installation of a computed tomographic (CT) scanner in the emergency department (ED) of a hospital include consideration for overall efficiency (reduced transportation time and cost), improvement in patient care (proximity to treatment areas), and high ED patient volumes. As the nation struggles to contain the costs of medical care, however, one issue that arises is whether the utilization of this scanner leads to more efficient patient care. This may become increasingly true as EDs get busier and the evaluation of the patients by the physician gets delayed. The temptation to use the scanner as a surrogate physical examination arises in these cases.

In the past, placement of other diagnostic machinery in the hospital has led to increased utilization. Bedside radiographic systems and intraoperative magnetic resonance imaging units are examples where “proximal” imaging has led to an increase in the utilization and number of units placed in hospitals in the United States. Institutions rarely perform cost-benefit analyses for such units, and...
Table 1
Summary of Findings according to Anatomic Location

<table>
<thead>
<tr>
<th>Anatomic Site</th>
<th>Major Findings</th>
<th>Minor Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>Fracture, intracranial hemorrhage, acute ischemic disease, neoplasm, vascular malformation, infection, herniation</td>
<td>Age-related and chronic ischemic disease, atrophy, structural abnormalities, soft-tissue and bone changes, ventricular enlargement, ventriculoperitoneal shunting, inflammatory sinus and mastoid disease</td>
</tr>
<tr>
<td>Face</td>
<td>Fracture, collection, hemorrhage, infection, neoplasm, vascular malformation-mass</td>
<td>Inflammatory sinus and mastoid disease, soft-tissue and bone changes, postoperative expected changes</td>
</tr>
<tr>
<td>Cervical spine</td>
<td>Spinal fracture, collection, hemorrhage, cord compression, neoplasm, vascular malformation, mass, dislocation and herniation of disk, infection</td>
<td>Degenerative cervical disease, structural abnormalities, soft-tissue and bone changes</td>
</tr>
</tbody>
</table>

the imaging devices are often justified on the basis of patient care.

In 1999, a CT scanner was installed in the ED adjacent to the patient holding area at our institution. A noticeable increase in case volume occurred within months. The general perception by the neuroradiologists interpreting the scans, however, was that the positive rate of neuroradiology cases from the ED decreased. Was the increase in case volume disproportionately in the form of normal examinations? To study this issue, we performed an analysis of CT scans reviewed by members of our neuroradiology division before and after installation of the CT unit in the ED. This study was designed to look at the changes in the utilization of CT, not the clinical effect of the CT scanner.

**MATERIALS AND METHODS**

From the radiology information system, we obtained the number of brain, face, and cervical spine CT scans ordered through the ED in 1998, the year before the CT scanner was installed in the ED, and 2000, a year after the scanner was installed. We included all requested scans arising from the ED such that CT utilization was not underestimated. To determine whether the change in the value reflected merely the change in the number of overall patient visits during that time, we obtained the total number of ED visits for these years, as well. We used a Fisher exact test to compare utilization rates from 1998 to 2000.

The positive study rate was based on review of patient records, including the CT report and record of hospitalization. Our sampling frame was 500 consecutive scans matched for a time period of each year (January 1, 1998, to February 17, 1998, and January 1, 2000, to February 6, 2000). Imaging findings were classified as major, minor, or normal. The major and minor findings are summarized in Table 1. Major findings were those that necessitated prompt treatment, hospitalization, or a change in patient care. Minor findings were those that would not affect a patient’s care or that were unrelated to the complaints at presentation.

Because we defined major findings as those that affected patient care, we also classified each scan as positive if care was affected because of the imaging findings and negative if the findings did not change the care. Negative studies included normal studies and those with minor findings. A neuroradiologist (K.K.O.) reviewed the radiology reports and subsequently classified each scan as containing major, minor, or normal findings. The scans were also categorized on the basis of the type of examination: brain, face, and cervical spine and/or neck. The reviewer was not blinded to the year the scan was obtained.

We tested the hypothesis that proximity of a CT scanner to the ED results in a decreased percentage of major findings and decreased percentage of positive findings with a null hypothesis of no difference and an α of .05. Positivity and negativity, as well as major, minor, and normal findings, were recorded as proportions with an assumption of normality and, thus, were amenable to χ² analysis. For this analysis, we compared CT scanner utilization rates before and rates after installation in the ED, the proportion of major, minor, and normal findings, and the proportion of positive and negative scans.

There were no changes in ED personnel or philosophy during the study period. The procedure for ordering a CT
examination in the ED also did not change between 1998 and 2000. As far as can be ascertained, there were no changes in the demographics of the patients who came to the ED during this interval. The studies were interpreted by residents and/or fellows with an attending physician present during the daytime (7:00 AM to 6:00 PM), by a neuroradiology fellow in the evening until 11:00 PM with the cases checked in the morning by an attending physician, and by an on-call resident from 11:00 PM to 7:00 AM with the cases checked in the morning by an attending physician.

RESULTS

In 1998, the year before the CT scanner was installed in the ED, 3,884 of the 48,866 patients (8.0%) who were treated in the ED underwent at least one neuroradiologic CT examination. In 2000, the year after the CT scanner was installed in the ED, 6,569 of the 50,611 patients (13.0%) who were treated at the ED underwent at least one neuroradiologic CT examination. There was a statistically significant increase in the utilization rate from 1998 to 2000 (P < .001, Fisher exact test) (Table 2) and a 69.1% increase in overall volume ([6,569 - 3,884]/3,884). The overall departmental volume of CT studies increased by 26% (36,399 examinations in 1998 and 46,028 in 2000). Part of the overall increase obviously includes the increase in ED volume (without the ED volume, the overall departmental percentage increase was 21%).

Of the first 500 neuroradiologic studies obtained as samples from 1998 and 2000, the radiologic reports from 471 and 452 studies, respectively, were available for evaluation from the radiology information system. In most cases, the absent reports were due to the fact that the scans were never officially read. Most studies were brain CT scans (367 of 471 [78%] in 1998 and 371 of 452 [82%] in 2000).

A comparison of scan findings according to scan type is summarized in Table 3. Although the rate of normal brain, normal face, and normal spine studies increased from 1998 to 2000 by as much as 9.5%, the difference was significant only for facial CT scans (P = .002). The positive scan rate for facial examinations decreased from 63% to 31% (45 of 71 scans in 1998 and 17 of 54 scans in 2000) after the CT scanner was installed in the ED (P < .001, Fisher exact test). The decrease was also dramatic for cervical spine studies, with positive scan rates of 27% in 1998 and 11% in 2000 (nine of 33 scans in 1998, three of 28 scans in 2000; P = .12). As noted in Table 4, the effect was smaller for brain CT scans. To further address the difference in positive scan rates for the cervical spine in a small sample size, we performed a power analysis and, on that basis, reviewed 20 additional cervical spine studies from each year. These additional cases showed a trend toward statistical significance (P values decreased from .12 to .10 with additional subjects, Fisher exact test).

When all types of scans were analyzed together, the positive scan rates were significantly lower after CT scanner installation (P < .01, Fisher exact test).

In the patients who underwent neurologic CT examination, trauma was the most common reason for all three types of examination (ie, brain, face, cervical spine). Other common referral reasons were headache, change in mental status, stroke, seizure, headache, and mental status change in patients infected with the human immunodeficiency virus. In addition, neurologic CT was performed to assess the functional status of ventriculoperitoneal shunts (Table 5). Of the various indications, there was a statistically significant decrease in positive brain CT scans (from 34% in 1998 to 15.8% in 2000) for those with a history of head trauma (P < .001, Fisher exact test). A downward trend (P = .14, Fisher exact test) was also noted for those studies performed for seizures (positive rate of 20.6% in 1998 and 8.3% in 2000).

DISCUSSION

Advances in imaging techniques have led to remarkable changes in patient care. After the clinical introduction of CT scanners in the 1970s, their availability increased rapidly. Scanning times have declined, and image quality has increased tremendously. Patient throughput is a major challenge for EDs. As the reliance on imaging techniques for patient care increases, limited access to imaging is an impedance to efficient patient care and
Table 3
Distribution of Findings according to Anatomic Location

<table>
<thead>
<tr>
<th></th>
<th>Normal Finding</th>
<th>Minor Finding</th>
<th>Major Finding</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>131/367 (35.7)</td>
<td>159/371 (43.0)</td>
<td>186/367 (50.7)</td>
<td>253/371 (68.3)</td>
</tr>
<tr>
<td>Face</td>
<td>9/71 (12.7)</td>
<td>12/54 (22.2)</td>
<td>17/71 (23.9)</td>
<td>25/54 (46.3)</td>
</tr>
<tr>
<td>Cervical spine</td>
<td>14/33 (42.4)</td>
<td>13/28 (46.4)</td>
<td>10/33 (30.3)</td>
<td>12/28 (42.9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note.—Numbers in parentheses are percentages.
*Values were obtained with the χ² test.

Table 4
Distribution of Normal Studies and Studies with Minor Findings Combined versus Studies with Major Findings

<table>
<thead>
<tr>
<th></th>
<th>Minor and Normal Findings</th>
<th>Major Findings</th>
<th>P Values*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>317/367 (86.4)</td>
<td>323/371 (87.0)</td>
<td>50/367 (13.6)</td>
</tr>
<tr>
<td>Face</td>
<td>28/71 (36.6)</td>
<td>37/54 (68.5)</td>
<td>45/71 (63.4)</td>
</tr>
<tr>
<td>Cervical spine</td>
<td>24/33 (72.7)</td>
<td>25/28 (89.3)</td>
<td>9/33 (27.3)</td>
</tr>
<tr>
<td>Overall</td>
<td>367/471 (77.9)</td>
<td>385/452 (85.0)</td>
<td>104/471 (22.1)</td>
</tr>
</tbody>
</table>

*Values were obtained with the Fisher exact test.

Table 5
Summary of Referral Reasons for CT Examination

<table>
<thead>
<tr>
<th>Year</th>
<th>Trauma*</th>
<th>Strokelike Symptoms</th>
<th>Seizure</th>
<th>Headache</th>
<th>Change in Mental Status</th>
<th>Human Immunodeficiency</th>
<th>VentriculoPeritoneal Shunt Malfunction</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>209 (34)</td>
<td>46 (13)</td>
<td>34 (20.6)</td>
<td>39 (13)</td>
<td>21 (9.5)</td>
<td>14 (7.1)</td>
<td>13 (0)</td>
<td>96 (12.6)</td>
<td>471 (22)</td>
</tr>
<tr>
<td>2000</td>
<td>196 (15.8)</td>
<td>43 (9.3)</td>
<td>36 (8.3)</td>
<td>43 (9.3)</td>
<td>40 (7.5)</td>
<td>12 (8.3)</td>
<td>11 (0)</td>
<td>71 (31)</td>
<td>452 (15)</td>
</tr>
</tbody>
</table>

Note.—Data are given as numbers of cases. Numbers in parentheses are the percentage of positive scans (scans with at least one major finding).
*There was a statistically significant decrease in the number of positive brain CT scans from 1998 to 2000 (P < .05).

Throughout. Reduced transportation, time, and cost and overall efficient patient care are the main reasons for installing a CT scanner in the ED. This leads to reorganization of EDs for fast and efficient patient transport between scanner and ED beds. With the fast and accurate diagnosis enabled with CT, there have been questions about costs and overutilization of this technology. To our knowledge, although cost-analysis studies have appeared in the literature, the effect of an ED CT scanner on utilization and positive scan rates has not been studied (1-7).

We sought to determine whether the presence of a CT scanner in the ED affects its utilization rate as a diagnostic tool. Beyond that, most radiologists have a perception that clinicians may use CT as a triage tool before physical examination in busy EDs. We found that there was a significant increase in the utilization rate between the year before and the year after installation of a CT scanner in the ED at our institution. With the scanner in the ED, an increase in the number of examinations is not unexpected because transportation of debilitated patients becomes easier. When we analyzed the data, we found that the rate of normal studies increased by 7.3% (brain), 9.5% (facial), and 4.2% (cervical spine) once the CT scanner was installed in the ED. At the same time, the rate of significant major findings decreased across the three body regions (0.6% for brain, 31.9% for facial, and 16.6% for cervical spine studies). This diminution in the number of studies with major findings that changed patients' diagnostic and therapeutic treatment was statistically significant for all neuroradiologic examinations (P < .01).
and facial CT examinations ($P < .001$), and a trend toward statistical significance ($P = .10$) was seen for cervical spine CT examinations. Positive rates of brain CT performed for head trauma also decreased significantly, from 34% to 15.8%. Trauma was the most common reason for all types of CT examinations, as one might expect for an ED.

Diagnostic evaluation of patients with minor head injury is usually performed to detect intracranial hematoma (8). Whether CT should be performed in all patients with minor head injury has been debated, and management protocols after minor head injury vary among countries and even among hospitals in the same country (8–14). Murshid (13) performed a retrospective study of 566 cases in which skull radiographs had been obtained and stated that skull radiographs were unnecessary after minor closed-head injury. In another study (14), Murshid recommended performing CT in patients with minor head injuries only in the presence of abnormal Glasgow Coma Scale score, neurologic deficit, signs of basilar depressed fracture, and progressive headache and vomiting. Duus et al (9) concluded that, in the care of patients with minor head injuries, clinical examination and follow-up were safe and neuroimaging could be excluded in the ED. In contrast to those studies, Ingebrigsten and Romner (15) compared three different management protocols in trauma patients who had no neurologic deficits and a Glasgow Coma Scale score of at least 14. The protocols included (a) CT scanning at admission and in-hospital observation for 24 hours, (b) CT scanning only in cases of suspected clinical deterioration, and (c) routine CT scanning at admission and discharge in cases of a normal examination. They concluded that an early normal posttraumatic CT scan could safely replace in-hospital observation and that the management protocol could cost less (15). Similarly, Shackford et al (16) studied 2,766 patients with minor head injury and found that 59 patients with normal neurologic examinations ultimately required a craniotomy for intracranial abnormalities. On the basis of the predicted hospital charges, the authors recommended performing CT in every patient with minor head injury even if the neurologic examination results are normal. They favored discharge of patients with normal results of neurologic and CT examinations (16).

In trauma patients, because cervical spine fractures may not be clinically apparent and 5%–8% of patients with fractures may have normal radiographs (in addition to the difficulty in positioning patients), cervical spine CT has been recommended as a screening method (17–21). Moreover, because it would save time and cost less than separate examinations, cervical CT at the time of head CT in trauma patients has been advocated (20). Blackmore and colleagues (22–24) performed a cost-effective analysis study in patients with trauma by using a clinical prediction rule to categorize patients into high-, moderate-, or low-risk groups. They found that substitution of cervical spine CT—performed at the time of head CT—for conventional radiography was cost-effective in the high- and moderate-risk groups because it would prevent cases of spinal cord injury and resulting paralysis, a financial burden for the society. In the low-risk group, however, they demonstrated a less beneficial prevention of spinal cord injury (24). Therefore, an appropriate clinical examination of trauma obviates CT and, thus, saves time, costs, and human resources.

The need for an appropriate clinical history and physical examination in cases of headache, stroke, seizure, extracranial malignancy, and vocal cord paralysis has been also emphasized (25–41). In a study by Fabbrini et al (25), there was no difference in the number of CT scans ordered before and after the introduction of International Headache Society criteria. Fabbrini et al found that only 12 of 2,739 scans revealed substantial abnormalities, probably unrelated to headache, and concluded that an improved definition of headache could help decrease the cost of diagnostic work-up. Results of other studies supported the very low yield of CT in patients with headache (26–28). In a retrospective study of 592 patients with headache but normal neurologic findings (26), CT reports were reviewed and graded as normal studies, minor abnormalities (eg, ischemic and atrophic changes), and gross intracranial abnormalities that could change patient care. The authors found no serious intracranial abnormalities on CT scans. In our study, the rate of major findings was 12.82% in 1998 and 9.30% in 2000, which suggests that clinical evaluation might lead to more appropriate selection of cases for scanning.

Chen et al (42) performed an analysis similar to ours and also found a 30% increase in cranial CT utilization in the 12 months after installation of a CT scanner in the ED in 1993. The positive study rate, however, was steady at 12.3% and 12.2% for the time before and after the CT scanner was installed, respectively. Chen et al looked only at cranial CT examinations, and the positive yield rate of 12% compares closely with our rates of 13.6% and 13.0% for brain CT. Because Chen et al did not include facial CT scans or cervical spine CT scans, they may not have detected the overall difference in positive
study rates in a neuroradiologic service. Previous studies of ED CT units have shown positive study rates of 15.7% (43) and 19% (44), but these may vary based on the criteria for “positivity.”

This study did not include an analysis of shifts in study patterns, for example, from plain radiography of the cervical spine or facial bones to CT of those body parts. The capacity to perform plain radiography did not change during the study period. The study was focused on positive scan rates in a neuroradiology practice. We also did not focus on the effect of the CT unit on length of stay and length of ED visits, patient outcomes, inpatient admissions, inpatient scans, or the potential positive downstream economic impact associated with a positive or negative CT scan. The perspective was from a CT-neuroradiology service rather than the effect on the ED or, for that matter, plain radiography (radiographs are not read by members of the neuroradiology division). This was also not reviewed from a cost-benefit analysis or from the standpoint of appropriateness criteria because this was a retrospective study. Therefore, we do not mean to infer conclusions of overuse or underuse of CT in the ED setting. The value of this study is in the prediction of volume increase effects of installing a scanner in the ED and on positive scan rates. One should expect a significant increase (from 30% in the study by Chen et al [42] to 69% in our study) in the volume of cases with similar positive scan rates in brain studies, a significant increase (from 31% in the study by Chen et al [42] to 69% in our study) in the volume of cases with similar positive scan rates in the facial bones, and a trend toward lower positive scan rates in the cervical spine. Making appropriate staffing changes to accommodate the CT volume differences would be wise.

In conclusion, the installation of a CT scanner in the ED leads to increased utilization in neuroradiologic cases, controlling for the number of patient visits. With this increased utilization, we found that the overall rate of positive studies decreased, particularly for facial CT. This may be due to a change in ED practice patterns as the scanner is used as a surrogate triage instrument.

REFERENCES


1023