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An Evidence-Based Approach to the Efficient Use of CT-imaging in the Neurosurgical Patient

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Abstract

Background—Computed tomography (CT) is the current standard for rapidly diagnosing some of the more common structural pathologies that affect the neurosurgical patient peri-operatively. With this convenience comes the potential for over-utilization which is associated with increased cost and radiation exposure.

Methods—All head CT studies ordered by the UCLA neurosurgery department from 8/15/2011-12/15/2011 were prospectively studied. Variables collected included: demographic information, diagnosis, surgical procedures, indication for CT, CT result, and whether the study led to a documentable change in management.

Results—There were 801 head CT studies ordered for the 462 patients who were admitted to the neurosurgical service. The authors identified fourteen indications for ordering a head CT with the following probabilities of a positive finding: exam change (17/56, 30.3%), follow-up(4-6 hours after intracerebral hemorrhage) (16/126, 12.7%), CT-angiogram (11/30, 36.7%),routine post-operative imaging (6/126, 4.7%), post-ventriculostomy placement (4/62, 6.5%), immediatley prior to (4/31, 12.9%) or after removal (2/42, 4.8%) of a ventriculostomy, surveillance (>24 hours after intracerebral hemorrhage or EVD placement) (3/66, 4.5%), headaches (2/8, 25%), ground level fall (1/8, 12.5%), intracranial pressure (ICP) spikes (2/6, 33.3%) and delayed (6-24 hours after intracerebral hemorrhage) (1/25, 4%).

Conclusions—The probability of discovering a clinically significant finding varies widely for each of the listed study indications. This prospective analysis of all CTs ordered at a single institutions suggests that imaging studies obtained without a change in neurological status were unlikely to produce a positive finding and even when positive were extremely unlikely to result in any intervention.

INTRODUCTION

Computed tomography (CT) scanning was introduced in the 1970s and is now among the most widely used imaging modality in a wide array of clinical settings. It is fast, non-invasive, readily available in most hospitals and provides definitive diagnostic information on the most common neurosurgical complications and conditions. Without question, these advances have greatly improved the ability of physicians to detect and diagnose a multitude of diseases and traumatic injuries. However, with this added convenience comes the potential for overuse. While computed tomography imaging carries less risk than prior more invasive techniques, excess scans result in increased financial burden, exposure to radiation, and strain on nursing and transport personnel. [1–3]

Cost

Over the past decade, the cost of health care in the United States has increased at a rate greater than twice that of general inflation. Current health care costs equal about 16% of the US gross domestic product. If this growth rate is left unchecked, health care costs will equal 20% of the GDP by 2015 and according to the Congressional Budget Office, 47% of the GDP by 2082. If spending increases remain linear with time, the estimated unfunded Medicare debt at that time will be approximately $34 trillion. During the past decade, imaging services and their costs have grown at about twice the rate of other technologies in health care e.g. prescriptions and laboratory studies. [2]

Radiation

Medical imaging is the largest man-made source of radiation exposure to the general population. From 1980 to 2006 the annual radiation dose received by the population of the United States increased by a factor of 7.1. [3] It is generally accepted that this increased exposure leads to some increased risk of developing cancer. Incorrectly calibrated machines have caused individual over-exposure[4] but if used correctly, the risk to an individual is probably small because the radiation doses are usually low. However the large number of studies obtained yields a larger threat on the population level. [5]

Nursing ratios and personnel burden

While overall nursing ratios and hours of care provided by nurses has increased since the mid-1990s, [67] surveys indicate that this increase is insufficient and given the increased complexity of care, it is now more difficult to provide adequate care and that the quality of care is deteriorating.[81] Part of this increased strain may be due to the increased need for transport to and from imaging procedures. While it is difficult to calculate the risk of transporting a critically ill patient to the CT scanner, it is known that increasing the patient to nurse ratio, as is required during the transport of critically ill patients, leads to increased mortality [9101112] as well as morbidity.[13, 14]

Despite these downsides, some publications have suggested that as many as 20%-50% of high-tech imaging procedures are unnecessary and unlikely to provide useful clinical information.[155] There are many factors leading to this overutilization including payment mechanisms and financial incentives, defensive medicine, and patient expectations. Further, when an incorrect, redundant or inappropriate imaging study is ordered, few hospitals have a formalized protocol to notify and educate the ordering physician to prevent further errors in the future.

In order to increase the yield of clinically useful scans, analyses are necessary to identify the indications for imaging that are most likely to provide useful information. As of now the optimal management of patients with neurosurgical pathologies is not clearly defined. While several studies have looked at the utility of obtaining a second delayed CT in the setting of minor head trauma [16171819], no study to date has looked at the utility of the other types of imaging studies ordered by a neurosurgical service.

The goal of this study was to prospectively evaluate the utility of cranial CT scans in all patients admitted to a neurosurgical service at a tertiary referral and Level I trauma hospital. We hypothesized that different indications for head CTs would have different probabilities of revealing a positive finding and of resulting in a change in patient management. With the information of which indications are likely to reveal a clinically useful finding, clinicians can better identify which scenarios justify imaging.

Methods

Consecutive patients admitted either electively or through the Emergency Department from 8/15/2011-12/15/2011 were prospectively entered into a clinical database. The indication for all head CTs was recorded along with the result of that imaging study and whether the imaging resulted in a change in patient management. Demographic and clinical information including patient age, gender, diagnosis dates of admission and discharge, and discharge location (home, rehab, or sub-acute nursing facility) were also recorded. Before initiating prospective data collection, the authors identified 14 indications for scanning based on the clinical practice patterns. The 14 categories included:

1. Exam Change, which included any significant change in neurologic status including, seizures, focal deficit or alteration in mental status or level of arousal. If a scan was obtained after an exam change this scan was classified as an “exam change” even if another indication also applied e.g. “post-pull” or “post-operative.” Conversely any scan under another indication can be assumed to be obtained without an exam change.

2. Diagnostic, which includes any CT obtained by the emergency department or consulting service that leads to a neurosurgical consultation.

3. Follow-up, which includes CT studies obtained 4-6 hours after any acute hemorrhage
4. CT angiogram
5. Post-operative, including all routine post-operative studies
6. Post-ventriculostomy (EVD), including all studies obtained immediately after ventriculostomy placement
7. Pre-pull, including scans obtained immediately prior to planned discontinuation of a ventriculostomy after successful weaning, usually intended to ensure the absence of hydrocephalus before removing the ventriculostomy
8. Post-pull, including studies obtained after the removal of a ventriculostomy to rule out intraventricular hemorrhage
9. Surveillance, including scans ordered more than 24 hours following any hemorrhage or ventriculostomy manipulation
10. Delayed, which includes scans obtained 6-24 hours after initial hemorrhage after a stable follow-up scan
11. Headaches
12. Ground level fall, including scans obtained after ground level falls sustained **while an inpatient** without neurologic symptoms
13. ICP spikes
14. Preoperative studies

Descriptive analyses were performed on demographic information and baseline clinical data. Chi-square analysis was performed using GraphPad Prism6.01 for Windows, (Graphpad Software, La Jolla California USA, www.graphpad.com). This study was approved by the University of California, Los Angeles Institutional Review Board.

Results

During the four month study period 462 patients were admitted to the neurosurgical service and all patients were included in this study. Out of those 462 patients, 233 patients received at least one head CT scan. The number of scans per patient ranged from 0 to 12. Ninety-eight patients received only one brain CT scan. Of those patients who were scanned, the median number of scans was two. The patient who received 12 scans had a history of platelet dysfunction and spontaneous intracerebral bleeding. The case break-down and admission type are displayed in Figure 1 and demographics are shown in Table 1.

The total number of studies ordered per indication is detailed in Figure 2. Likewise, the number of scans per indication with "positive findings" and that resulted in changes in the clinical care of the patient are detailed in Figure 2.

Diagnostic

During the study period, consulting services obtained 200 CT brain scans showing lesions or pathology that led to a neurosurgery consult. There is little neurosurgeons can do to reduce this number and is thus only included to illustrate the number of CT scans these patients are receiving.

Follow-up (i.e., within 4-6 hours of initial presentation with intracranial hemorrhage)

The neurosurgery service obtained 126 scans during the study period of which sixteen (12.6%) showed progression or blossoming of the hemorrhage. Of those sixteen patients, the discovery of bleed progression led to the decision to evacuate the lesion via craniotomy/ craniectomy in three patients (2.3% of all follow-up studies obtained).

Delayed

During the study period 25 delayed scans (i.e., 6-24 hours after a prior stable exam) were obtained. One of these scans (4%) showed worsening hemorrhage but did not lead to a change in management.

Surveillance

Sixty-six surveillance scans (i.e., >24 hours after initial presentation with prior documentation of stability of intracranial pathology) were obtained during the study period. The most common reasons for the surveillance scan were poor baseline neurological exam, long-term patient was being sent to outside facility, or a ward patient who previously had a difficult to wean ventriculostomy. Three patients showed increased ventricular size. Two of these patients were managed conservatively without surgical intervention and the other underwent replacement of his ventriculostomy.

Exam Change

Of the fifty-six scans obtained for an exam change, seventeen showed worsening hydrocephalus(64%) or hemorrhage(36%). Eight of these resulted in active change in management (14% of studies) including either evacuation or CSF drainage. The other nine scans were managed conservatively.

CT-angiogram

Thirty patients with initial CT studies suspicious for underlying vascular pathology underwent a second contrast enhanced CT scan leading to the discovery of nine aneurysms, one tumor and one arteriovenous malformation (36% of all studies). The discovery of any of these underlying lesions significantly alters their diagnosis and subsequent management.

Pre-operative study

Fifteen patients required pre-opeartive CTs before undergoing surgery.

Post-operative Study

126 post-operative scans were obtained. Six studies (4.8%) revealed new findings in 6 patients who were already in the ICU with stable neurological exams, including two

cranioplasty patients who were found to have subdural hemorrhage post-operatively and four patients who were found to have either recurrent bleeding at the site of hematoma evacuation or a new site of remote bleeding. None of these patients received ICP monitoring. The only change in management was in one patient (0.8%) with a recurrent hemorrhage after a hematoma evacuation who was taken directly from the CT scanner back to the operating room.

Post-Ventriculostomy

Sixty-two ventriculostomies were placed during this period, all of which were imaged immediately after the procedure. Four abnormal findings were identified (6.5%), including two studies with small non-operative hemorrhages and two studies documenting misplaced ventriculostomies (despite CSF return) requiring revision (3.2%).

Pre-pull

Thirty-one patients underwent a CT scan prior to removal of the ventriculostomy. Prior to removal four of these patients were found to have worsening hydrocephalus by imaging (12.9%) and the ventriculostomies were left in place and the patients were referred for surgical shunting.

Post-pull

Of the forty-two patients who received post-pull scans, two had IVH (4.8%). Their neurological exams were stable and thus the ventriculostomy was not replaced.

Headaches

Eight patients complained of severe headaches and were evaluated with a head CT. Two of these patients (25%) were found to have slightly larger ventricles. Neither patient received CSF diversion.

Ground level fall

Eight head CTs were ordered after ground level falls, one patient with a previous intracerebral hemorrhage was found to have a slightly larger hemorrhage (13%) which was managed conservatively.

ICP spikes

Six patient had ICP spikes and two of them were found to have previously undiscovered ischemic strokes.

Using a chi-square analysis comparing the above indications to “exam change,” seven of the indications were found to be significantly less likely to reveal a new finding (“follow-up” “Surveillance” “Post-op” “EVD” “Delayed” “Pre-pull” and “Post-pull”). Ordering a CT angiogram yielded a similar number of positive findings and “Headache” “Ground Level” and “ICP spikes” had too few entries to be statistically significant. In regards to influencing management six of the indications were significantly less likely than “exam change” to change the plan of care (“Follow-up,” “Surveillance” “Post-op” “EVD” “Delayed” “Post-pull”). Interestingly “pre-pull” was not significantly different than “exam change” due to the fact that the discovery of enlarged ventricles always prevented removal of the ventriculostomy.

Discussion

We prospectively analyzed the utilization pattern of CT imaging in a neurosurgical department in a single center in order to identify the most common indications for ordering a head CT and the relative clinical utility of each of these indications. Although the patient population and spectrum of problems and clinical scenarios is diverse, we were able to identify fourteen indications that accounted for all CT scans ordered over a four month period. The yield of clinically useful studies varied widely across the various indications. Not surprisingly, CT studies obtained after documented changes in neurological status frequently revealed a new radiographic finding and given the change in neurological status, the physicians involved were more likely to intervene on that finding. Conversely, studies obtained without a neurological change (post-pull, surveillance, delayed, post-operative) were both unlikely to detect an abnormality and when a new finding was identified, these were almost always treated conservatively without further intervention. Interestingly, every indication did reveal at least one new finding, however the post-pull and surveillance studies never led to a change in management.

The revolution in medical imaging has provided a means of rapidly obtaining qualitative and quantitative information about the anatomy and physiologic features of most organ systems. It is now the gold standard for detecting injuries and many disease processes including hydrocephalus, cerebral edema and herniation. These advances have allowed millions of persons to avoid more invasive and costly diagnostic procedures. However, the ease and convenience of these tools has made them vulnerable to over-utilization. The increased use of these services has placed an increased financial burden on the healthcare system, radiation exposure to patients, and strain on nursing ratios and support personnel to transport these often critically ill patients.

Cost

For most neurosurgery patients the reimbursement is based on diagnosis or procedure and not on a list of individual services provided. However, each service the hospital provides sends an annual report on the cost to maintain that particular service. At our institution we obtained the costs for all services provided to our patients over the course of one year 1/2010-1/2011 (Figure 3). The total annual cost for providing care was $56 million. Imaging services, of which CT is the largest portion, constitutes 8% of the total cost of providing care. Approximately half of that cost is for CT scans while the other half is for MRI imaging. Although, some parts of this cost are fixed and not dependent on the number of studies obtained, an estimate of the cost per study is $1000/CT scan. However in each clinical scenario this cost must be weighed against the potential risk in health or liability of not ordering a study.

Radiation

Current radiation protection standards and practices are based on the premise that any radiation dose, no matter how small, can result in detrimental health effects such as cancer or other genetic damage. [15] The risk to any one individual is probably small because radiation doses are usually low but the large number of people exposed annually means that even small individual risks could translate into a considerable number of cancer cases. The best estimates of cancer risk come from two studies. The first examine the increased cancer incidence and radiation exposure in the populations of Nagasaki and Hiroshima and extrapolating backwards. Using this model it was estimated that each CT scan of the head leads to a 0.07% increase in lifetime risk of cancer. [20] No patient during our study received more than twelve studies and the majority received three or fewer studies. However using the previous estimates, over the course of a year's use, 3200 CT studies would yield 2.2 cancers. The second is from Pearce et al. In this retrospective study the authors identified 74 cases of leukemia and 135 brain tumors from a cohort of 178,604 children and determined that radiation exposure from a CT scan before the age of 10 significantly increased the risk for these cancers. However, because they are relatively rare cancers it would take approximately 10,000 scans to yield one additional case of leukemia or brain cancer. [21] These estimates are, however, clouded by approximations and uncertainties. Until this controversy is resolved, physicians must be vigilant of this risk and minimize radiation exposure by limiting the number of low-yield studies.

Nursing ratios and personnel burden

Concerns of inadequate nurse staffing in hospitals and its potential adverse impacts on quality of care have been expressed in both the popular press [22,23] and in the professional literature [24,25,26]. Prior research has documented an inverse relationship between nurse staffing and mortality [9,10,11,12] as well as other adverse events including pneumonia[13], urinary tract infections and deep vein thrombosis[14]. While the actual CT scan takes only a few **seconds**, the transport of the patient can take thirty minutes or more. While a nurse is occupied in this activity, his or her other patients must be covered by other nurses who are now working at a higher patient to nurse ratio and are unable to provide the same level of attention and care. In critically ill patients who are intubated, the patient must additionally be accompanied by a respiratory therapist who during that time would not able to respond to other emergencies that may occur. Some institutions may be able to circumvent this problem with a portable CT scanner. However, it has been our experience that the portable CT scanner is significantly more cumbersome and requires more time and personnel than the standard scanner and is largely limited to intra-operative use or in those patients who cannot be moved e.g. prone positioning for severe hypoxemia.

Clearly the solution is to order only those CT studies which are needed and likely to provide useful information. For many areas of medicine, appropriateness criteria have been developed. However, they are not well known and their use is voluntary. As a consequence, these criteria are not frequently employed. These appropriateness criteria are not perfect and have several flaws. First these guidelines are based on the consensus opinion of experts rather than objective clinical evidence. Second, these criteria are often based on an already established diagnosis when often the diagnosis is unknown and not obvious.

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Limitations

There are inherent weaknesses to this study. **First a CT scan that does not show any new finding may still have clinical value**. CT scans placed after placement of ventriculo-peritoneal shunts may be helpful as a baseline by which to compare future ventricle size. Likewise, an unchanged CT scan may allow the physician to feel more confident about prescribing anti-coagulation or anti-platelet agents. Second, a positive CT finding that was managed conservatively may have nevertheless led to increased vigilance by the nursing staff and physician team and thus improved care. Third, the slow nature of prospective data-gathering limits the number of scans that were analyzed and may subject the current analysis to sampling error. As such some of the more infrequent categories e.g. headache, ground-level fall, and ICP spikes had few entries. However, the goal of this study was not necessarily to be comprehensive but to gain insight into patterns of practice and the utility of CT scans across various indications. As opposed to rigorous scientific studies, in the arena of health care improvement, the path to improvement lies in identifying opportunities for improvement and building upon those in a sequential fashion. Despite the limited sample, the results of this study identify such opportunities.

Neuroimaging via computed tomography has become a powerful diagnostic tool in the arsenal of the astute clinician. The appropriate use of this tool on a large scale will require practice guidelines based on valid clinical evidence. The guidelines should be well publicized, easily and quickly accessible and frequently used with deviation when deemed necessary.

It should be understood that every clinical situation is different and it is up to the clinician to decide on the appropriate indications for imaging, however in the case of the neurosurgical patient, this study seems to support that many studies that are ordered routinely without a change in neurological status (post-pull, delayed, surveillance, post-operative) yield relatively few new findings and the trend is for these rare findings to be treated conservatively. While these results inform us of the relative value (or lack thereof) of routine studies, these are not intended to dictate that such studies are never indicated. Clearly, clinical judgment must prevail.

Future Directions

There is understandable reluctance on the part of clinicians to accept restrictions on the use of clinical resources among neurosurgical patients, a population at high risk for disastrous complications. This reluctance is based on the assumption that a more liberal use of resources will yield better care and better outcomes. In the era of evidence-based medicine it is important to not only observe usage patterns but to make interventions and prospectively confirm there are no harmful effects on patient care. To this end, UCLA Neurosurgery has eliminated the use of routine CT imaging after removal of a ventriculostomy and is now prospectively following this cohort to verify both patient safety (no adverse events) as well as efficacy (fewer CT scans). If this measure is successful we will consider expanding our efforts in limiting the number of CT scans obtained for other indications.

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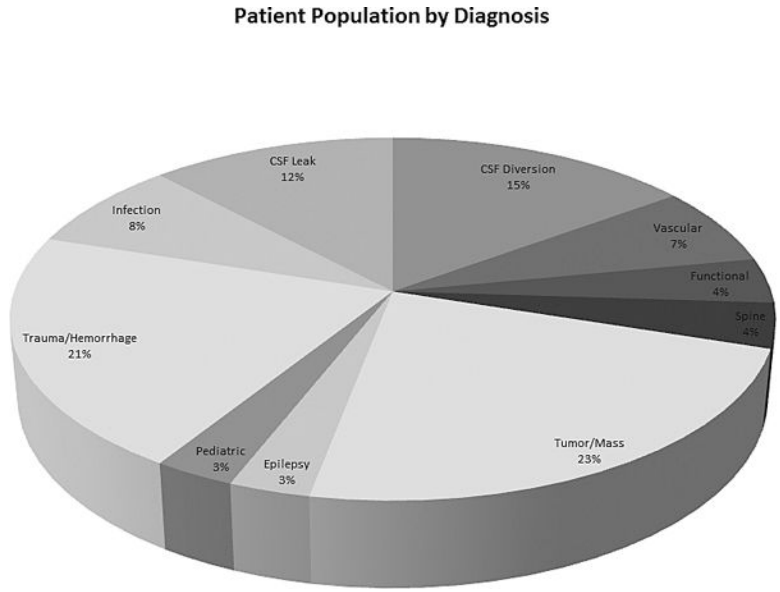
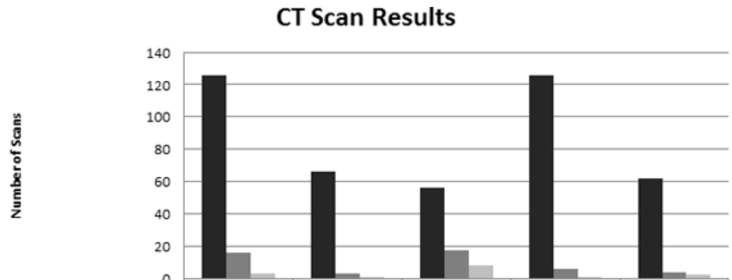
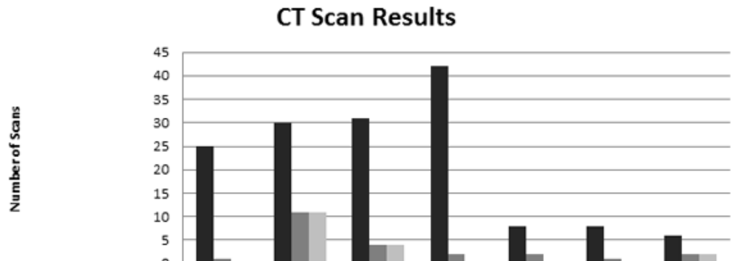


Figure 1.
Patient distribution by diagnosis 8/15/2011-12/15/2011.



	Follow-up	Surveillance	Exam Change	Post-op	EVD
Total CT Scans	126	66	56	126	62
Positive Findings	16	3	17	6	4
Change in Management	3	1	8	1	2



	Delayed	CT-angiogram	Pre-pull	Post-pull	Headaches	Ground Level	ICP Spikes
Total CT	25	30	31	42	8	8	6
Positive Finding	1	11	4	2	2	1	2
Change in Management	0	11	4	0	0	0	2

Figure 2.

All CT studies of the head were prospectively analyzed and categorized by their indication. The chart demonstrates all CTs ordered for a particular indication those that revealed a previously unknown finding and the number of times that new finding led to a change in management.

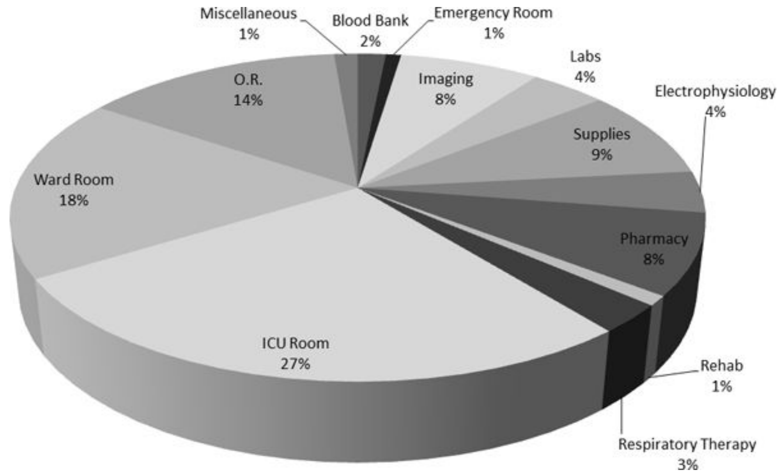


Figure 3.

Total costs for all services rendered for the year (1/1/2011-1/1/2011) were tabulated and analyzed. The total cost for all services provided was $56 million. The pie chart demonstrates the relative contribution of each service provided.

Table 1

Demographics of the prospective database.

Demographics	
Age (Average,range)	48.9±23.8 years
Male Gender	47.6%
Length of Stay	6.9±8.2 days
Placement	
Home	65%
Rehab	22%
SNF	13%
Admission Type	
Elective	40%
ER	44%
Transfer	13%
Consult	3%