The clinical significance and optimal timing of postoperative computed tomography following cranial surgery

Clinical article

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Object. This study was conducted to evaluate the value of postoperative CT scans in determining the probability of return to the operating room (OR) and the optimal time to obtain such scans to determine the effects of surgery.

Methods. Between January and December 2006 (12 months), all postoperative head CT scans obtained for 3 individual surgeons were reviewed. Scans were divided into 3 groups, which were determined by the preference of each surgeon: Group A (early scans—scheduled between 0 and 7 hours); Group B (delayed scans—scheduled between 8 and 24 hours); and Group C (urgent scans—ordered because of a new neurological deficit). The initial scans were reviewed and analyzed in 2 different fashions. The first was to analyze the efficacy of the scans in predicting return to the OR. The second was to determine the optimal time for obtaining a scan. The second analysis was a review of serial postoperative scans for expected versus unexpected findings and changes in the acuity of these findings over time.

Results. In 251 (74%) of 338 cases, the patients had postoperative head CT scans within 24 hours of surgery. Analysis 1 determined the percent of patients returning to the OR for emergency treatment based on postoperative scans: Group A (early)—133 patients, with 0% returning to the OR; Group B (delayed)—108 patients, with 0% returning to the OR; and Group C (urgent)—10 patients, with 30% returning to the OR (p < 0.05). Analysis 2 determined the optimal timing of postoperative scans and changes in scan acuity: Group A (early scan) had an 11% incidence of change in acuity on subsequent scans. Group B (delayed scan) had a 3% incidence of change in acuity on follow-up scans (p < 0.05).

Conclusions. Routine postoperative scans at 0–7 hours or at 8–24 hours are not predictive of return to the OR, whereas patients with a new neurological deficit in the postoperative period have a 30% chance of emergency reoperation based on CT scans. In addition, early postoperative scans (0–7 hours) fail to predict CT changes, which might evolve over time and may influence postoperative medical management. (DOI: 10.3171/2009.11.JNS081048)

KEY WORDS • cranial surgery • postoperative neuroimaging • computed tomography

Abbreviations used in this paper: OR = operating room; SDH = subdural hematoma.

Postoperative CT scans are a variable part of routine neurosurgical practice, often being dictated by an individual surgeon’s preference, training culture, and practice. Reasons for a scan include, but are not limited to, assessing the extent of tumor resection; accuracy of catheter/implant placement; detection of hemorrhage, edema, or ischemia; and evaluating ventricular size. The comfort of the surgeon is also certainly an important factor, as is the educational value of the CT scan. The timing of these studies and their efficacy with regard to impacting patient care remain undefined. In an era of diminishing medical resources and reimbursement, and escalating malpractice awards, the role and efficacy of postoperative imaging requires further investigation. A trip to the CT scanner is not without significant risk and resource use. A vulnerable patient can end up in a potentially hostile environment. Transportation of patients involves multiple personnel of varying skills, and

nursing staff who are taken away from their other unit responsibilities. These scans also often interfere with the workflow efficiencies of the radiology department. Finally, the radiation exposure from CT scan is not negligible; a typical CT scan delivers 20 millisieverts. An increased risk of cancer has been reported at levels of radiation equivalent to 2–3 scans. A similar argument has been advanced for the use of CT angiography in patients with cardiovascular disease, in whom the risk of cancer is weighed against the potential benefits from CT.

In this study, we examined the value of postoperative head CT scans in influencing the clinical course of patients as it related to return to the OR, and sought to define the optimal timing to obtain a postoperative CT following cranial surgery.

Methods

Inclusion Criteria

All postoperative CT scans obtained after elective and emergency craniotomies for the period from January
to December 2006 at Loyola University Medical Center for 3 individual surgeons were reviewed. The pattern of scanning—early (0–7 hours, directly postoperative/same day) or delayed (8–12 hours, following morning/next day)—was determined by surgeon practice preference. Urgent scans were determined by the results of clinical examination or by a new and/or unexpected postoperative finding on examination. Patient demographic information, along with diagnosis, type of intracranial surgery, presence of implants, and the timing of the CT scan were reviewed. The cases were divided into 1 of 11 categories (Table 1). Cases involving implants (deep brain stimulators, Ommaya reservoirs, external ventricular drains, and ventricular shunts) were excluded from the study.

Protocol for CT Scans

The CT imaging studies were performed using either GE Light Speed (GE Healthcare) or Somatom Sensation (Siemens AG) platforms. Our standard technique includes a sequential acquisition from the base of the skull to the vertex, with orbital meatal gantry tilt. The CT scan is obtained with 5-mm slice thickness and spacing, with a table feed of 5 mm per rotation, using 120 kV and 180–550 mA at 1–2 seconds rotation time, and a 25-cm field of view. This translates into a CT dose index of 67.

Timing of CT Scan

All postoperative CT scans were reviewed and analyzed. In our first set of analyses, the scans were grouped according to the postoperative latency, which was determined by physician practice behavior, as follows: Group A (early) was scheduled between 0 and 7 hours; Group B (delayed) was scheduled between 8 and 24 hours; and Group C (urgent) was ordered because of a new neurological deficit. For the purpose of this analysis, a new neurological deficit included a patient who was slow to wake up (characterized by exceeding the calculated anesthetic reversal time), a change in neurological examination findings, unexpected neurological examination, or prolonged intubation with no confirmed neurological examination. The rate of patients returning to the OR for emergency treatment was calculated.

Defining Expected Versus Unexpected Findings on Postoperative CT Scans

In the second set of analyses, all initial postoperative head CT scans were categorized for acuity as follows: 1) expected postoperative findings; or 2) unexpected (subclinical) postoperative findings in the head CT.

Unexpected postoperative findings included intracerebral hemorrhages, extradural hematomas, and SDH. Furthermore, the unexpected changes were subcategorized for acuity as follows: Category I, minor changes not requiring any intervention, which included small hemorrhages in the tumor bed, persistent SDH, and minor bleeding in the surgical bed. Category II, the intermediate classification, might require further observation or change in management, including large interventricular hemorrhage, hemorrhage causing mass effect, and hemorrhage compressing the fourth ventricle. Category III included CT scans that prompted surgical reexploration.

Follow-up CT scans (a second scan obtained within 96 hours of the initial postoperative CT) were examined and evaluated for changes, and were recategorized as described above. The change in acuity was noted when there

| TABLE 1: Categories of cranial cases and number of cases that were treated by each of the 3 neurosurgeons* |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Category                        | Description                     | Surgeon 1 | Surgeon 2 | Surgeon 3 | Total |
| supratentorial                  | meningiomas, primary & secondary tumors | 18 (19) | 35 (21) | 21 (11) | 74 (16) |
| tumor                           | aneurysm, AVM, STA-MCA bypass    | 10 (11) | 4 (2) | 11 (6) | 25 (5) |
| vascular                        | includes cranioplasty          | 15 (16) | 41 (25) | 21 (11) | 77 (17) |
| trauma                          | includes brain abscess, wound infection, temporal lobectomy, CSF leak repair, brain biopsy, & encephalocele repair | 13 (14) | 18 (11) | 14 (7) | 45 (10) |
| other                           |                                 |           |           |           |        |
| vascular                        | includes microvascular decompression | 3 (3) | 0 (0) | 10 (5) | 13 (3) |
| trauma                          |                                 | 1 (1) | 1 (1) | 0 (0) | 2 (<1) |
| other                           | Chiari malformation decompression, CSF leak repair, & encephalocele repair | 4 (4) | 0 (0) | 19 (10) | 23 (5) |
| infratentorial                  |                                 |           |           |           |        |
| tumor                           |                                 | 5 (5) | 6 (4) | 46 (23) | 57 (12) |
| vascular                        |                                 | 3 (3) | 0 (0) | 10 (5) | 13 (3) |
| trauma                          |                                 | 1 (1) | 1 (1) | 0 (0) | 2 (<1) |
| other                           |                                 | 4 (4) | 0 (0) | 19 (10) | 23 (5) |
| Ommaya/EVD/shunts               |                                 | 15 (16) | 53 (32) | 46 (23) | 114 (25) |
| functional                      | deep brain stimulator          | 0 (0) | 0 (0) | 5 (3) | 5 (1) |
| transsphenoidal approaches      | includes pituitary surgery & CSF repair | 10 (11) | 9 (5) | 3 (2) | 22 (5) |
| total                           |                                 | 94 (100) | 167 (100) | 196 (100) | 457 (100) |

* AVM = arteriovenous malformation; EVD = external ventricular drain; MCA = middle cerebral artery; STA = superficial temporal artery.
Value of head CT scans following cranial surgery

### Results

**Analysis 1: Percent of Patients Returning to OR Based on Postoperative Scans**

Between January and December 2006 (12 months), there was a total of 457 cranial cases (Table 1). Cases involving implants (119 cases) were excluded from the analysis. Of the remaining 338 cases, 251 (74%) had an initial postoperative head CT scan within 24 hours of operation and were available for analysis. Two distinct practice patterns were observed: Surgeon 1 predominately (89%) obtained early postoperative CT scans (0–7 hours); and Surgeons 2 and 3, who predominately obtained a delayed head CT (8–24 hours; 91 and 78%, respectively). Of the 251 scans obtained within the first 24 hours, 133 (53%) fell into Group A, early scans; 108 (43%) fell into Group B, delayed scans; and 10 (4%) were categorized as Group C, urgent scans (Table 2). Returns to the OR based on scan findings were as follows: Group A, 0%; Group B, 0%; and Group C, 30% (p < 0.05).

### Discussion

In an era of increasing demand for evidence-based medicine, tradition, training culture, and personal practice behaviors based on experience are still the primary driving forces for many of today's clinical practices. One of the most common and frequently obtained studies in a neurological surgery practice is the head CT scan. At our institution over the past 10 years, several practice patterns were observed, including no CT, scans performed directly from the recovery room, and routine scans obtained 24–48 hours postoperatively. These studies, while seemingly innocuous, are demanding of personnel and resources.
resources, and can expose the patient to a more unprotected environment. This retrospective study is an initial step in establishing evidenced-based, uniform practice by comparing 2 distinct surgeon practice patterns (early postoperative and delayed postoperative CT scanning) and their influence on patient return to the OR. A prior study performed at our institution demonstrated that with posterior fossa surgery, there was a 17% incidence of subclinical CT abnormalities, with no patient requiring a return to the OR. This prompted a change in our practice to eliminate these studies, except in the face of a new, unexpected neurological finding.

Our data support the conclusion that a new, unexpected neurological finding is the most significant factor that will lead to emergency return to the OR (30%). Similar results were seen at the Cleveland Clinic. In this study of almost 5000 cranial cases, 40 (0.8%) required return to the OR. All 40 cases had a change in examination findings, and 32 of the 40 had a CT scan confirming hemorrhage. These data are similar to what is found in the head trauma literature. In one study, 17 (38%) of 45 went to the OR after a CT scan was obtained because of a neurological deficit and only 1% of the entire population (2 of 247 patients) in whom a routine head CT was obtained and who needed to undergo surgical intervention. In a similar study, 7 (4%) of 179 patients with mild head injury needed operative intervention. All 7 had a change in examination results. The authors concluded that a routine, repeat head CT scan in patients who presented with mild traumatic injury was unnecessary. In another study, a repeat head CT for mild head injury was unnecessary, with a negative predictive value of 100% in patients with normal findings on neurological examination.

Postoperative head CT scanning does allow for evaluation of edema, hematoma, air, ventricular size, evidence of ischemia, and device placement. Magnetic resonance imaging to evaluate the extent of tumor resection has been found to be superior to CT. Findings on head CT studies can lead to changes in medical management, patient disposition, and delivery of implanted devices. To optimize the benefit of scanning, the optimal time to obtain the study to evaluate the consequences of intervention is key.

**Timing of CT Scan**

Early scans may actually give a false sense of security, leading to patient dispositions in which less frequent neurological examination and monitoring are performed. This is demonstrated by our data, in that of the 14 patients who had a change in the acuity of their CT scans, 13 had undergone CT scans within 4 hours of surgery, and those were either initially normal or had minor changes.

The trauma literature sheds considerable light on the timing of head CT scans after traumatic brain injury. There is an almost 50% progression of hemorrhage on a follow-up CT if the initial head CT scan was performed with 2 hours of injury. In addition, epidural hematoma enlargement can occur up to 36 hours after injury. Fifty percent of patients who exhibit traumatic subarachnoid hemorrhage will demonstrate progression of the hemorrhage if the initial head CT was performed during the first 2 hours. In our study, we observed a similar profile, in which early scans were more likely to fail to demonstrate the full consequence of the surgical intervention.

**TABLE 3: Second analysis of CT timing data**

<table>
<thead>
<tr>
<th>Groups &amp; CT Timing</th>
<th>% in Category*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>Group A: direct, scheduled btwn 0 &amp; 7 hrs</td>
<td>27</td>
</tr>
<tr>
<td>Group B: delayed, scheduled btwn 8 &amp; 24 hrs</td>
<td>23</td>
</tr>
<tr>
<td>Group C: emergency, ordered because of a new neurological deficit</td>
<td>40</td>
</tr>
</tbody>
</table>

* Initial head CT scans were obtained within 24 hours of surgery, and unexpected findings were subcategorized for acuity for minor changes (Category I), intermediate changes requiring further observation or change in management (Category II), or findings that prompted surgical reexploration (Category III).
† p < 0.05.
Subsequent scans (up to 96 hours postsurgery) revealed worsening acuity in 11% of cases when the initial CT scan was obtained directly from recovery (within 8 hours of surgery), versus 3% when the initial CT scan was obtained in a delayed fashion (within 8–24 hours) (p < 0.05). This demonstrates that an early CT scan is more likely to fail in predicting changes that may ultimately impact management. A delayed scan is more likely to yield this important information.

Conclusions

Our study demonstrates that routine postoperative scans at 0–7 hours or at 8–24 hours were not predictive of return to the OR. An unexpected change in the neurological examination was the single most influential factor in outcome as it relates to reoperation. Furthermore, postoperative CT scans done too early underpredict the ultimate changes in the scans, which may lead to changes in future management. Cost-effective, evidence-based care requires judicious use of quantity and extent of technology. The low-cost, simple, but elegant neurological examination appears to be superior to a routine CT scan in determining return to the OR. Delaying the scan at least 8–24 hours will maximize the benefit for both patient and managing physician.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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References