Relevance of early head CT scans following neurosurgical procedures: an analysis of 892 intracranial procedures at Rush University Medical Center

Clinical article

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Object. Early postoperative head CT scanning is routinely performed following intracranial procedures for detection of complications, but its real value remains uncertain: so-called abnormal results are frequently found, but active, emergency intervention based on these findings may be rare. The authors’ objective was to analyze whether early postoperative CT scans led to emergency surgical interventions and if the results of neurological examination predicted this occurrence.

Methods. The authors retrospectively analyzed 892 intracranial procedures followed by an early postoperative CT scan performed over a 1-year period at Rush University Medical Center and classified these cases according to postoperative neurological status: baseline, predicted neurological change, unexpected neurological change, and sedated or comatose. The interpretation of CT results was reviewed and unexpected CT findings were classified based on immediate action taken: Type I, additional observation and CT; Type II, active nonsurgical intervention; and Type III, surgical intervention. Results were compared between neurological examination groups with the Fisher exact test.

Results. Patients with unexpected neurological changes or in the sedated or comatose group had significantly more unexpected findings on the postoperative CT (p < 0.001; OR 19.2 and 2.3, respectively) and Type II/III interventions (p < 0.001) than patients at baseline. Patients at baseline or with expected neurological changes still had a rate of Type II/III changes in the 2.2%–2.4% range; however, no patient required an immediate return to the operating room.

Conclusions. Over a 1-year period in an academic neurosurgery service, no patient who was neurologically intact or who had a predicted neurological change required an immediate return to the operating room based on early postoperative CT findings. Obtaining early CT scans should not be a priority in these patients and may even be cancelled in favor of MRI studies, if the latter have already been planned and can be performed safely and in a timely manner. Early postoperative CT scanning does not assure an uneventful course, nor should it replace accurate and frequent neurological checks, because operative interventions were always decided in conjunction with the neurological examination.

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KEY WORDS • computed tomography • radiography • craniotomy • reoperation • traumatic brain injury

The introduction of CT imaging in the 1970s has profoundly altered the practice of medicine in general and neurosurgery in particular; its inventors were justifiably awarded the Nobel Prize in 1979. Routine postoperative head CT scanning has since become a common practice; however, the origins of this habit are unclear, as is the evidence supporting it. Significant concerns over radiation exposure, costs, and hospital logistics involving excessive CT scans have arisen in the last 10 years. It has been recently estimated that patients with aneurysmal subarachnoid hemorrhage receive a mean cumulative radiation dose of 2.76 Gy during the index hospitalization. Stein et al. reported that 26.3% of patients with newly diagnosed hydrocephalus received doses >150 mSv to the ocular lens through CT scanning within 3 years of diagnosis. On the other hand, recent evidence involving head trauma and other general neurosurgical indications have suggested that a large fraction of CT examinations may be unnecessary.

Based on these concerns over unnecessary costs and radiation exposure, we sought to analyze our practice of obtaining early postoperative CT scans to determine if this led to early detection of complications and treatment. Our hypothesis is that early postoperative CT scans performed in intact patients did not detect pathological entities requiring emergency surgical intervention.
Methods

This study is a retrospective chart review of all intracranial procedures performed at Rush University Medical Center (RUMC) by the 10 surgeons in the Department of Neurosurgery between 01/01/2010 and 12/31/2010. This study was submitted to the RUMC Institutional Review Board and considered exempt. Our institutional protocol mandates that patients who have undergone any intracranial procedure be cared for in the first 24 hours postoperatively within our Neurosciences Intensive Care Unit (ICU), a 28-bed unit staffed with specialized intensive care physicians and nurses. Hourly neurological examination checks are performed during these 24 hours and early postoperative CT scans (< 4 hours) are obtained.

Two of the authors (R.B.V.F. and A.P.S.) reviewed the electronic medical record system to include all procedures performed in the main operating rooms and at bedside and listed under our staff member names. After initial screening, a total of 953 open intracranial procedures were identified. Sixty-one procedures (57 patients) were excluded from the study. The main reason for exclusion was absence of immediate postoperative CT scans due to surgeon’s preference (59 cases). These 59 cases comprise a mix of deep brain stimulation (in patients who underwent MR imaging), suboccipital decompression for Chiari malformation, and transsphenoidal resection of pituitary tumors, for which no imaging was deemed necessary. As for the 2 remaining cases, one patient died before CT scans could be obtained and one patient with glioma underwent immediate MRI studies.

In all, 892 procedures were identified. Patient and procedure data are listed in Table 1. Both elective and emergency/urgent cases were included; a significant portion (332 procedures, 37.2%) also involved placement of an intracranial device, most frequently a ventricular catheter. We used a methodology for analysis that was slightly modified from that of Khaldi et al. Preoperative and postoperative progress notes and physical examination performed by the residents and faculty members of our department were reviewed and patients grouped in one of four categories according to immediate postoperative neurological examination findings: A, baseline; B, expected changes (including only focal deficits consistent with manipulation of eloquent cortical area or cranial nerve); C, unexpected changes; and D, comatose or sedated (the latter also included patients already comatose at baseline).

Early postoperative CT images were reviewed, along with the progress notes documenting their interpretation by the members of our service, their subsequent actions, and the outcome. The CT findings were classified into expected or unexpected (Fig. 1). Unexpected findings were further subdivided based on the actions then taken by the neurosurgery team: Type I, no active intervention except for heightened observation measures through additional imaging or longer ICU stay; Type II, active nonsurgical intervention, such as medical intracranial pressure management; and Type III, active surgical intervention, either at bedside or in the operating room. It is important to note that no imaging interpretation was performed by the authors of this study because retrospective analysis could introduce bias, but this last classification was purely based on the treating physicians’ interpretation at the time of imaging. The patients’ hospital course was reviewed until discharge, and delayed complications were also noted. The occurrence of unexpected CT results and Type II or III interventions in Groups B, C, and D was compared with Group A by using the Fisher exact test, at a significance level of 0.05 (Prism 6, GraphPad Software).

Results

Our results are briefly summarized in Fig. 1 and Tables 1 and 2. The vast majority of our patients were grouped into the A (neurological baseline) or D (sedated or comatose) categories. No difference was found in the incidence of unexpected CT findings between Groups A and B (Table 2). The incidence of unexpected changes was significantly higher in Groups C (unexpected change) and D (sedated or comatose). A sedated or comatose patient was 2.3 times more likely to have a postoperative CT with unexpected results; on the other hand, an unexpected postoperative
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**Neurological exam**
- A - Baseline 627 (70.3%)
- B - Expected change 38 (4.7%)
- C - Unexpected change 23 (2.6%)
- D - Comatose 200 (22.4%)

**CT findings**
- Unexpected
- Types II and III
- Misplaced catheter - 10
- Hematoma - 4
- Type I
- 3 (5.2%)

**Intervention**
- Bedside adjustment - 6
- Elective repositioning - 4
- Delayed RTO - 4 (>8 hours + new CT)

**Approximately 90% of patients in Groups A and B** had the expected postoperative findings on CT scans; most patients with unexpected findings required a longer ICU stay and/or additional CT imaging, but no active intervention was necessary. Any interventions performed in Groups A and B were done in an elective and/or delayed fashion (following additional imaging and/or a period of clinical observation) or consisted of minor bedside adjustments—either retracting a few centimeters or completely removing a misplaced external ventricular drain (Fig. 1). No patient in Groups A or B had imaging findings that demanded an immediate return to the operating room.

**Groups C and D,** however, both contained cases for which CT findings dictated an immediate return to the operating room; furthermore, unlike Group A, bedside insertion of new ventricular catheters or intracranial pressure monitors (procedures considered active surgical intervention in our service and this study) was also required.

**Discussion**

Routine postoperative CT imaging is obtained for two reasons: assessment of surgical technique and detection of complications. It also allows for the establishment of a new “anatomical baseline” in the postoperative patient, to which subsequent scans will be compared. Prior

**TABLE 2: Case distribution per neurological examination group***

<table>
<thead>
<tr>
<th>Neurological Examination</th>
<th>Unexpected</th>
<th>Expected</th>
<th>p Value</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>expected change</td>
<td>4</td>
<td>38</td>
<td>0.552</td>
<td>1.30 (0.44–3.80)</td>
</tr>
<tr>
<td>unexpected change</td>
<td>14</td>
<td>9</td>
<td>&lt;0.001</td>
<td>19.20 (7.89–46.69)</td>
</tr>
<tr>
<td>sedated or comatose</td>
<td>31</td>
<td>169</td>
<td>0.001</td>
<td>2.26 (1.39–3.68)</td>
</tr>
<tr>
<td>baseline</td>
<td>47</td>
<td>580</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Each group was analyzed on a 2 × 2 format against the baseline group; p value is for the Fisher exact test.

**Fig. 1.** Flow chart showing summary of study results. EVD = external ventricular drain; ICP = intracranial pressure; RTO = return to operating room.
to the advent of the CT imaging modality, neurosurgeons had considerable trouble diagnosing postoperative complications due to the lack of specific angiographic features of some common postoperative findings, such as intracerebral hemorrhage, edema, and necrotic brain tissue. Postoperative CT scans tend to be obtained as early as possible following cranial surgery (sometimes immediately upon arrival to the ICU), theoretically to enable early treatment of significant abnormalities. As a method to assess surgical technique, postoperative CT scanning can be highly valuable, particularly within the context of a training program. However, for this specific reason it need not be performed urgently following an intervention, especially when there are other medical priorities. Furthermore, it has been supplanted by MRI in specific situations such as surgery for intrinsic tumors, where extent of resection cannot be accurately estimated with CT scanning and MRI studies may also be used to plan for adjuvant therapy.

Complications are inherent to surgery and can be expected to occur in a percentage of neurosurgical patients. Kalfas and Little reported 40 cases of postoperative hematomas requiring medical or surgical intervention out of 4992 cranial procedures (0.8%). Interestingly, they reported a similar rate for both craniotomies and smaller procedures involving bur holes only. The cases reported by Kalfas and Little represent true complications because management was modified and surgical intervention was required in most of them. The occurrence of postoperative CT findings considered “abnormal” by different criteria (such as interpretation by a radiologist) is far higher. Horowitz et al. reported that 25% of patients undergoing vestibular schwannoma resection had abnormal postoperative findings on CT scans, but only 8% of the changes resulted in symptoms. Fukamachi et al. reviewed 168 epidural hematomas that developed after 1055 intracranial procedures (15.9%); the vast majority (152 of 168) were small and regional, that is, located under the craniotomy flap or bur hole. None of these small regional hematomas had clinical implications and therefore none required evacuation. Overall, only 10 of the 168 hematomas required surgical intervention, which is a figure dramatically different from those found in any trauma series. Deterioration of imaging features has been demonstrated with repeat imaging in traumatic subarachnoid hemorrhage, subdural hematomas, and intraparenchymal hematomas, but not necessarily related to a change in neurological condition.

Whereas so-called abnormal postoperative CT findings are a common occurrence, postoperative neurological deterioration is not. Unexpected clinical deterioration in neurosurgical patients is known to correlate highly with progression of prior imaging abnormalities and also new pathology. This has been demonstrated in unselected neurosurgical patients, traumatic brain injury (TBI), vascular pathology, and in the postoperative period. When neurological deterioration is not verifiable—for example, as in the case of a patient with poor results on baseline examination or under sedation—the value of routine imaging has also been demonstrated, with detection of new pathology and worsening of preexisting findings. Khaldi et al. have recently demonstrated that early postoperative scans may have a very low predictive value, but when performed in the context of neurological deterioration, 30% required active intervention.

Based on the evidence reviewed above, the concept of obtaining routine head CT scans at predetermined points in time has been challenged, particularly for the awake and cooperative patient with TBI. Sifri et al. studied a group of 161 patients with mild head injury; 99 of these patients had normal results on neurological examination at the time of their predetermined repeat head CT, and in none of them was a change in management indicated based on the repeat CT. Brown et al. further demonstrated that, of a group of almost 274 patients with TBI who underwent predetermined repeat head CT, none of the patients with mild TBI and unchanged neurological examination required a surgical intervention, resulting in 80 excess CTs. Garrett et al. have recently analyzed CT scans ordered for all indications within a large academic neurosurgical service; of 126 CT scans ordered postoperatively, only 1 (0.8%) resulted in a return to the operating room. It is not specified, however, if this was performed in an early manner or if there was a change in neurological examination.

The results presented here support the concept that routine postoperative CT scanning is not a priority for the awake and cooperative patient or those with new but predicted neurological deficits. Patients with unexpected neurological changes were 19.2 times more likely to have an unexpected finding on postoperative CT; on the other hand, no patients in the A and B categories required emergency neurosurgical intervention based on the results of early postoperative CT. This is to be expected because the decision to perform any surgical intervention is defined by the binomial of neurological examination and imaging findings—if one of these criteria is considered satisfactory, surgeons are reluctant to return to the operating room to simply “fix the CT.” It also corroborates what has been shown in TBI literature and smaller series of postoperative CTs. That is also the reason why we refrain from analyzing the sensitivity, specificity, and predictive values of postoperative CT findings for active postoperative management—it is an inherently flawed contingency analysis because the postoperative CT (“the test”) is one of the defining factors for which patients return to the operating room (“the disease”).

Due to the nature of our service and the referral pattern in our area, most of the procedures included in this study were elective. Although RUMC is only a Level II trauma center, there is a streamlined transfer system in place to allow patients within the greater Chicago area to be quickly transferred to RUMC for complex neurosurgical care. It has been estimated that approximately 80% of these emergency transfers would be unrelated to cranial trauma. This explains the elevated vascular/trauma ratio of emergency and urgent cases in our series and also the number of CSF diversion procedures. A significant number of Type III CT changes in our series consisted of improperly placed ventricular catheters (20 of 51 [39.2%]). In any large series with freehand placement of intracranial catheters, particularly if these hap-
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pen at bedside where ultrasound or navigational guidance is unavailable, misplacement will account for a significant number of reoperations. Inaccurate placement of ventricular catheters utilizing the freehand technique has been reported in the 15%–45% range.11,17,22 Misplaced catheters were managed in our service according to the patient’s neurological condition—if the patient was awake and stable, external catheters were simply removed and shunts were repositioned electively. If, on the other hand, the patient was sedated or comatose, the catheter was immediately repositioned at bedside (external catheters) or in the operating room (shunts).

A delayed postoperative CT scan has been suggested as being more useful than an early scan, because it would allow for hematoma accumulation and the need to return to the operating room to be more evident.13 The retrospective nature of our study does not allow for conclusions regarding timing; we did, however, immediately intervene in comatose or sedated patients when early CT scans revealed unexpected changes. It is unlikely that a retrospective study could answer this question, even if it included paired scans (early and delayed). Probably the only way to completely address the question of ideal timing is through a prospective randomized trial. We thus tend to favor a neurological examination–based approach: postoperative CT scans should not be a priority in the immediate postoperative period, as long as the patient has a satisfactory neurological examination. A CT scan is probably not even necessary in the majority of patients in whom an early MRI study is planned, as in the case of surgery for intraxial tumors and assessment of extent of resection. Within this database, 168 procedures for the resection of such tumors were identified after which the patient was awake and oriented and, accordingly, still underwent early postoperative CT. As described above, CT scans did not reveal alterations that demanded an immediate return to the operating room, but, regardless of the CT findings, these patients also underwent MRI to assess extent of resection. A minor change in protocol (MRI within 8 hours, for example) could have thus resulted in the cancellation of these 168 CTs in this study (18.9% of the total CTs performed) with no added cost or burden, since hourly neurological checks and MRI were already part of our postoperative routine. A final point to be considered is whether there are additional patient characteristics besides the neurological examination results that would affect the decision to obtain early imaging, such as age or comorbidities; future prospective studies should be encouraged to look into this question.

Conclusions

Our review of the data presented here has demonstrated that early postoperative CT scans performed in awake patients or those with expected deficits did not result in a single emergency surgical intervention, thus confirming the study hypothesis. On the other hand, new, unexpected neurological findings were frequently associated with important new findings on CT scans, requiring emergency neurosurgical action. Early postoperative CT is thus not required on an emergency basis in awake patients, nor does it represent an “insurance policy” for the surgeon that all is well postoperatively. The inestimable value of the old-fashioned neurological examination performed by diligent, specialized nurses and physicians is reaffirmed once again.

Disclosure

Dr. Byrne is a consultant to Stryker and Integra. Author contributions to the study and manuscript preparation include the following. Conception and design: Fontes, Smith, Traynelis. Acquisition of data: Fontes, Smith. Analysis and interpretation of data: Fontes. Drafting the article: Fontes. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Fontes. Statistical analysis: Fontes. Administrative/technical/material support: Muñoz, Byrne, Traynelis. Study supervision: Traynelis.

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