Outpatient follow-up of nonoperative cerebral contusion and traumatic subarachnoid hemorrhage: does repeat head CT alter clinical decision-making?

Clinical article

*Sebastian Rubino, B.S., Rifat A. Zaman, B.A., Caleb R. Sturge, B.S., Jessica G. Fried, B.A., Atman Desai, M.D., Nathan E. Simmons, M.D., and S. Scott Lollis, M.D.

1Geisel School of Medicine at Dartmouth, Hanover; and 2Section of Neurosurgery, Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire

Object. Many neurosurgeons obtain repeat head CT at the first clinic follow-up visit for nonoperative cerebral contusion and traumatic subarachnoid hemorrhage (tSAH). The authors undertook a single-center, retrospective study to determine whether outpatient CT altered clinical decision-making.

Methods. The authors evaluated 173 consecutive adult patients admitted to their institution from April 2006 to August 2012 with an admission diagnosis of cerebral contusion or tSAH and at least 1 clinic follow-up visit with CT. Patients with epidural, subdural, aneurysmal subarachnoid, or intraventricular hemorrhage, and those who underwent craniotomy, were excluded. Patient charts were reviewed for new CT findings, new patient symptoms, and changes in treatment plan. Patients were stratified by neurological symptoms into 3 groups: 1) asymptomatic; 2) mild, nonspecific symptoms; and 3) significant symptoms. Mild, nonspecific symptoms included minor headaches, vertigo, fatigue, and mild difficulties with concentration, short-term memory, or sleep; significant symptoms included moderate to severe headaches, nausea, vomiting, focal neurological complaints, impaired consciousness, or new cognitive impairment evident on routine clinical examination.

Results. One hundred seventy-three patients met inclusion criteria, with initial clinic follow-up obtained within approximately 6 weeks. Of the 173 patients, 104 (60.1%) were asymptomatic, 68 patients (39.3%) had mild, nonspecific neurological symptoms, and 1 patient (1.0%) had significant neurological symptoms. Of the asymptomatic patients, 3 patients (2.9%) had new CT findings and 1 of these patients (1.0%) underwent a change in treatment plan because of these findings. This change involved an additional clinic appointment and CT to monitor a 12-mm chronic subdural hematoma that ultimately resolved without treatment. Of the patients with mild, nonspecific neurological symptoms, 6 patients (8.8%) had new CT findings and 3 of these patients (4.4%) underwent a change in treatment plan because of these findings; none of these patients required surgical intervention. The single patient with significant neurological symptoms did not have any new CT findings.

Conclusions. Repeat outpatient CT of asymptomatic patients after nonoperative cerebral contusion and tSAH is very unlikely to demonstrate significant new pathology. Given the cost and radiation exposure associated with CT, imaging should be reserved for patients with significant symptoms or focal findings on neurological examination.

Abbreviations used in this paper: GCS = Glasgow Coma Scale; SDH = subdural hematoma; TBI = traumatic brain injury; tSAH = traumatic subarachnoid hemorrhage.

* S. Rubino and R. Zaman contributed equally to this work.
Outpatient CT in nonoperative contusion and traumatic SAH

low risk for worsening after discharge: nonoperative cerebral contusion and traumatic subarachnoid hemorrhage (tSAH). We hypothesized that, for these specific indications, routine CT scanning of an asymptomatic patient is unlikely to alter the treatment plan.

Methods

Study Population

This study was performed in a single rural, academic, Level I trauma center. All data were reviewed retrospectively. For the period in question, it was standard practice among all participating providers to evaluate patients 4–6 weeks after discharge, with a CT scan obtained the same day; however, deviations from this practice did occur, based on clinical concern, scheduling constraints, and patient preference.

Prior to beginning the chart review, institutional review board approval and waiver of consent were sought and obtained. We then reviewed the hospital charts of all adult patients admitted to Dartmouth-Hitchcock Medical Center from April 2006 to August 2012 who had an admission diagnosis of cerebral contusion or tSAH and had at least 1 clinic follow-up examination with a CT scan. Exclusion criteria were concomitant epidural hematoma, subdural hematoma (SDH), aneurysmal SAH, intraventricular hemorrhage, and craniotomy for trauma.

Data Collection

Inpatient notes were reviewed for patient demographic data, type of lesion (cerebral contusion, tSAH, or both), mechanism of injury, presence of isolated head injury, bleeding tendencies on admission, length of hospitalization, and use of blood thinners on discharge. Clinic notes were reviewed for new neurological symptoms, and findings were stratified into 3 groups: 1) asymptomatic; 2) mild, nonspecific symptoms; and 3) significant symptoms. Mild, nonspecific symptoms included nonfocal symptoms known to occur after concussion, which were not severe enough to impair usual activities. This group included minor headaches, vertigo, fatigue, and mild difficulties with concentration, short-term memory, or sleep. Significant symptoms included symptoms interfering with activities of daily living and consisted of moderate to severe headaches, nausea, vomiting, focal neurological complaints, impaired consciousness, or new cognitive impairment evident on routine clinical examination.

Radiology reports and selected images were reviewed for relevant findings. Admission CT scans were reviewed for inclusion and exclusion criteria; clinic CT scans were reviewed for new or worsened findings.

Outcome Variables

The primary outcome measure was the frequency of abnormal radiological findings on clinic CT resulting in a change in treatment plan. This outcome measure was assessed in 3 subgroups: 1) asymptomatic patients; 2) patients with mild, nonspecific symptoms; and 3) patients with significant symptoms. Sensitivity, specificity, positive predictive value, and negative predictive value of symptoms at clinic follow-up were calculated.

Results

During the study period, 891 patients were admitted with the diagnoses of cerebral contusion or tSAH. Of these 891 patients, 508 were excluded because of concurrent extraxial hematoma, aneurysmal SAH or intraventricular hemorrhage, and craniotomy for trauma. Two hundred ten patients were excluded because they were either lost to clinic follow-up or did not have additional CT imaging after discharge. The final study cohort consisted of 173 patients; of these, 40 patients had only cerebral contusions, 75 patients had only tSAH, and 58 patients had both pathologies. Of the 98 patients with cerebral contusions, 63 patients had a single contusion and 35 patients had “multiple contusions” as described in their radiological report. No penetrating injuries were present within this cohort. Seventy-seven patients had bleeding tendencies on admission caused by anticoagulants, antiplatelet agents, liver disease, or alcohol abuse, and 22 patients were discharged on anticoagulants, antiplatelet agents, or both (Table 1).

Initial clinic follow-up was obtained within approximately 6 weeks: within 1 month in 57 patients, between 1 and 3 months in 111 patients, and after 3 months in 5 patients. Of the 173 patients evaluated in the clinic, 104 patients (60.1%) were asymptomatic; 68 patients (39.3%) had mild, nonspecific neurological symptoms; and 1 patient (0.6%) had significant neurological symptoms (Fig. 1).

The sensitivity and specificity of being symptomatic at follow-up and having a change in CT scan was 66.7% and 61.6%, respectively. The positive predictive value of

<table>
<thead>
<tr>
<th>TABLE 1: Cohort characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic</td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td>total no. of patients</td>
</tr>
<tr>
<td>mean age ± SD (yrs)</td>
</tr>
<tr>
<td>sex</td>
</tr>
<tr>
<td>male</td>
</tr>
<tr>
<td>female</td>
</tr>
<tr>
<td>type of injury</td>
</tr>
<tr>
<td>cerebral contusions</td>
</tr>
<tr>
<td>tSAH</td>
</tr>
<tr>
<td>cerebral contusions &amp; tSAH</td>
</tr>
<tr>
<td>bleeding tendencies on admission</td>
</tr>
<tr>
<td>total</td>
</tr>
<tr>
<td>anticoagulant (warfarin)</td>
</tr>
<tr>
<td>antiplatelet agent (aspirin or clopidogrel)</td>
</tr>
<tr>
<td>anticoagulant &amp; antiplatelet agent</td>
</tr>
<tr>
<td>liver disease</td>
</tr>
<tr>
<td>alcohol abuse</td>
</tr>
<tr>
<td>discharged on blood thinners</td>
</tr>
<tr>
<td>total</td>
</tr>
<tr>
<td>anticoagulant (heparin, enoxaparin, or warfarin)</td>
</tr>
<tr>
<td>antiplatelet agent (aspirin or clopidogrel)</td>
</tr>
<tr>
<td>anticoagulant &amp; antiplatelet agent</td>
</tr>
<tr>
<td>mean time to follow-up ± SD (wks)</td>
</tr>
</tbody>
</table>

* Unless otherwise specified, values indicate number (%) of patients.
being symptomatic at follow-up and having a change in CT scan was 8.7%. The negative predictive value of being asymptomatic at follow-up and having no change in CT scan was 97.1%.

Asymptomatic Patients

Of the 104 asymptomatic patients, 3 (2.9%) had new CT findings and 1 (1.0%) of these patients underwent a change in treatment plan because of these findings. This involved an additional clinic appointment and head CT to monitor a 12-mm chronic SDH that ultimately resolved without treatment. The other 2 patients exhibited a slight increase in ventricular size on CT; the treatment plan was not altered and follow-up was discontinued without adverse effects (Table 2). No asymptomatic patient with abnormal findings on follow-up CT required surgical intervention.

Patients With Mild, Nonspecific Neurological Symptoms

Of the 68 patients with mild, nonspecific symptoms, 6 (8.8%) had new CT findings and 3 of these patients (4.4%) underwent a change in treatment plan because of these findings. This involved an additional clinic appointment and head CT to monitor a 12-mm chronic SDH that ultimately resolved without treatment. The other 2 patients exhibited a slight increase in ventricular size on CT; the treatment plan was not altered and follow-up was discontinued without adverse effects (Table 2). No asymptomatic patient with abnormal findings on follow-up CT required surgical intervention.

Patients Discharged on Anticoagulants and/or Antiplatelet Agents

Of the 22 patients discharged on anticoagulants and/or antiplatelet agents, no patient had an increase in the size of the original cerebral contusion or tSAH and no patient developed any new extraaxial hemorrhage.

Discussion

This study suggests 3 general conclusions. First, repeat outpatient CT of asymptomatic patients after nonop-
Outpatient CT in nonoperative contusion and traumatic SAH

**TABLE 2: Asymptomatic patients with new CT findings**

<table>
<thead>
<tr>
<th>Age (yrs)*</th>
<th>Lesion</th>
<th>Bleeding Tendency on Admission</th>
<th>New Findings</th>
<th>Change in Treatment Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>56</td>
<td>tSAH</td>
<td>none</td>
<td>slight increase in ventricular size</td>
<td>no; clinic follow-up discontinued</td>
</tr>
<tr>
<td>76</td>
<td>contusions</td>
<td>none</td>
<td>12-mm chronic SDH</td>
<td>yes; further clinic follow-up and CT; self-resolved</td>
</tr>
<tr>
<td>79</td>
<td>tSAH</td>
<td>warfarin</td>
<td>slight increase in ventricular size</td>
<td>no; clinic follow-up discontinued</td>
</tr>
</tbody>
</table>

* All patients were male, had no symptoms at follow-up, and were neurologically intact on the follow-up examination.

Limitations of the Study

There are a number of methodological limitations in this study. First, it is retrospective and therefore suffers from selection bias and other related design limitations. While a common practice of scanning all patients with cerebral contusion and traumatic intracranial hemorrhage theoretically mitigates selection bias, there were a large number of patients in this study who did not undergo their planned surveillance CT scan. The reasons for this are not known in every case, and this is a potential source of bias. The study’s retrospective nature also introduces the inherent subjectivity of clinical decision-making. Decisions about when to discharge a patient from follow-up or whether a particular radiological finding explains a given symptom are two areas in which study conclusions might be colored by provider impressions.

Another limitation of the study is that we were unable to quantify the total number or size of lesions per patient due to variable charting. Some radiology reports only listed “multiple contusions” and not all CT scans were available for independent review. In the absence of a volumetric analysis, we cannot rule out the possibility that our patient cohort was skewed toward smaller hemorrhages; however, the authors feel that this type of generalizability problem is unlikely at a major trauma center that covers a large geographic region.

Current Practice

With health care reform aiming to achieve better health outcomes at lower costs, there is an increasing focus on evidence-based practice. Currently, many physicians obtain repeat head CT scans at the first clinic follow-up examination to evaluate a variety of possible delayed complications, including posttraumatic hydrocephalus, delayed extraaxial hematoma, and worsened cerebral edema; however, there are no data in the current literature to either support or refute these practices. Early prospective studies advocating serial routine head CT up to 3 months and 12 months after TBI have limited relevance, because patients in these studies had a clinical change in their examination findings, and the decision to undergo neurosurgical intervention was not made solely on routine CT findings.6

Although management of inpatient serial head CT is not the focus of this study, it is worth discussing the current literature regarding surveillance CT imaging in the inpatient setting. Currently, there is conflicting literature regarding serial head CT for inpatient management of mild, nonoperative head injury, in the absence of a decline in neurological examination results.1–3,6,7,9,13 Some studies have shown a lack of benefit2,6,7,9,14 while others support the usefulness of this practice.3,13 In one of the stronger studies, Brown et al. prospectively studied 354 patients with intracranial hemorrhage, stratifying their results by mild (Glasgow Coma Scale [GCS] score 13–15), moderate (GCS score 9–12), and severe (GCS score ≤ 8) head injury. Excluding patients with neurological decline, no patient with mild or moderate injury underwent medical or surgical intervention after routine repeat head CT.7 The authors therefore recommended routine repeat head CT only in patients with GCS scores ≤ 8. This study of inpatient management reflects our findings in the outpatient setting; no asymptomatic or minimally symptomatic patient underwent medical or surgical intervention based on routine repeat outpatient CT alone.

Medicolegal ramifications of undocumented radiological abnormalities also may be a significant driver of some physicians’ decisions to scan all patients. Clinicians may fear being blamed for a subsequent, unrelated pathology and thus may obtain imaging to document resolution of traumatic sequelae. Admittedly, this practice is unlikely to be altered by the findings of this study.

* Iatrogenic Cancer Implications of CT

The downside of excessive use of CT scanning is significant. Biological and biophysical data regarding radiation exposure supports a “linear-no-threshold” risk model, which stipulates that the risk of cancer proceeds in a linear fashion at lower doses and does not require an exposure threshold.10 Therefore, even the smallest dose of radiation has the potential to increase patients’ risk of developing cancer. The FDA estimates that a CT examination with an effective dose of 10 mSv may be associated with the development of fatal cancer in approximately 1 in every 2000 patients, whereas a report by the National Research...
Council predicts development of cancer in 1 in every 1000 patients.\textsuperscript{12} The effective dose of a standard head CT is 2 mSv. The linear-no-threshold model implies an additive nature to radiation exposure, which may quickly surpass 10 mSv when also accounting for serial CT scans that occur during hospitalization. Even if risk to any one individual is small, extrapolation of these data to the population level suggests the possibility of significant iatrogenic injury.

**Cost Implications of CT**

Cost is another rationale for eliminating routine CT scanning of the asymptomatic patient. According to the Healthcare Blue Book, a patient consumer website, the cost of nonenhanced head CT in our region is approximately $302 dollars; this includes both physician interpretation and technical imaging fees. Thus, the estimated total cost of routine outpatient CT scanning for our patient cohort was $52,246 ($302 × 173 patients). Of this total cost, at least 60%, or $31,408, would have been saved if outpatient CT scans had not been performed in asymptomatic patients. If an additional clinic visit, rather than a CT scan, were conducted in mildly symptomatic patients, the radiology savings would increase to 99.4%, or $51,932; however, this figure does not account for the additional cost of a clinic visit. Unfortunately, it is impossible to calculate the potential national savings for this practice change, because we do not know how many outpatient CT scans are conducted for nonoperative cerebral contusion and tSAH within the US.

**Logistical Challenges of Unscheduled CT Scans**

Admittedly, breaking away from a “scan everyone” policy poses logistical challenges to health care providers. If concerning symptoms are detected during a follow-up clinic visit, a patient may require the scheduling of a semi-urgent or urgent CT scan; he or she may subsequently need to return to clinic to review the results, and these efforts can be disruptive to a provider’s schedule. However, the authors believe that this disruption can be mitigated and that inconvenience alone should not be used to justify a test that is costly, potentially harmful, and of dubious benefit. The authors also acknowledge that the potential injury of a “missed” diagnosis in the neurosurgical realm is potentially devastating. This phenomenon is common to all reviews of neurosurgical practice, but research such as this gives our field a better framework within which to make clinical decisions.

**Conclusions**

Asymptomatic patients presenting to clinic for routine follow-up after nonoperative cerebral contusion and tSAH are at low risk for new structural pathology; therefore, it is reasonable to forgo outpatient CT in these patients. Patients with mild, nonspecific symptoms are at a slightly higher risk for new structural pathology, and a clinical approach to these patients may include cross-sectional imaging or solely additional follow-up. For patients with significant symptoms, the authors recommend cross-sectional imaging, although the current study did not include...
Outpatient CT in nonoperative contusion and traumatic SAH

a sufficient number of these patients to provide eviden-
tiary support for this recommendation.

Disclosure

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

Author contributions to the study and manuscript preparation
include the following. Conception and design: Fried, Desai, Sim-
mons, Lollis. Acquisition of data: Rubino, Zaman, Sturge. Analysis
and interpretation of data: Rubino, Lollis. Drafting the article:
Rubino, Lollis. Critically revising the article: all authors. Reviewed
submitted version of manuscript: all authors. Approved the final ver-
sion of the manuscript on behalf of all authors: Rubino. Statistical
analysis: Rubino. Study supervision: Lollis.

References

repeat cranial CT scans in patients with intracranial hemor-
rhage and GCS score of 13 to 15. J Trauma Acute Care Surg
2. Almenawer SA, Bogza I, Yarascavitch B, Sne N, Farrokhyar
F, Murty N, et al: The value of scheduled repeat cranial com-
puted tomography after mild head injury: single-center series
monitoring in patients with minimal brain injury. J Trauma
66:1015–1018, 2009
4. Berrington de González A, Mahesh M, Kim KP, Bhargavan M,
tomographic scans performed in the United States in 2007.
Arch Intern Med 169:2071–2077, 2009
5. Bodenheimer T: High and rising health care costs. Part 1: seek-
6. Brown CVR, Weng J, Oh D, Salim A, Kasotakis G, Demet-
riades D, et al: Does routine serial computed tomography of
the head influence management of traumatic brain injury? A
jizacharia P, et al: Indications for routine repeat head computed
tomography (CT) stratified by severity of traumatic brain in-
8. Cope DN, Date ES, Mar EY: Serial computerized tomographic
evaluations in traumatic head injury. Arch Phys Med Rehabil
9. Kaups KL, Davis JW, Parks SN: Routinely repeated computed
tomography after blunt head trauma: does it benefit patients? J
Trauma 56:475–481, 2004
10. National Research Council of the National Academies: BEIR
VII: Health Risks from Exposure to Low Levels of Ionizing
Radiation. Washington, DC: National Research Council of
the National Academies, 2005 (http://dels.nas.edu/resourcedes/
11. Roberson FC, Kishore PR, Miller JD, Lipper MH, Becker DP:
The value of serial computerized tomography in the manage-
gies to reduce the risk of radiation in CT studies, including
selective substitution with MRI. J Magn Reson Imaging 25:
900–909, 2007
13. Thorson CM, Van Haren RM, Otero CA, Guarch GA, Curia
E, Barrera JM, et al: Repeat head computed tomography after
minimal brain injury identifies the need for craniotomy in the
absence of neurologic change. J Trauma Acute Care Surg
74:967–975, 2013
and intensive care unit admission necessary in mild traumatic

Manuscript submitted October 8, 2013.
Accepted June 25, 2014.

The results of this study were presented at the New England Neu-
osurgical Society 2013 Annual Meeting in Brewster, Massachusetts,
in the form of an oral presentation.

Please include this information when citing this paper: published
online July 25, 2014; DOI: 10.3171/2014.6.JNS132204.

Address correspondence to: Sebastian Rubino, B.S., Section of
Neurosurgery, Geisel School of Medicine at Dartmouth, Dartmouth-
Hitchcock Medical Center, 1 Medical Center Dr., Lebanon, NH
03756-0001. email: sebastian.rubino.med@dartmouth.edu.