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Overnight Preliminary Head CT Interpretations Provided by Residents: Locations of Misidentified Intracranial Hemorrhage

BACKGROUND AND PURPOSE: Our aim was to determine the patterns of error of radiology residents in the detection of intracranial hemorrhage on head CT examinations while on call. Follow-up studies were reviewed to determine if there was any adverse effect on patient outcome as a result of these preliminary interpretations.

MATERIALS AND METHODS: Radiology residents prospectively interpreted 22,590 head CT examinations while on call from January 1, 2002, to July 31, 2006. The following morning, the studies were interpreted by staff neuroradiologists, and discrepancies from the preliminary report were documented. Patients' charts were reviewed for clinical outcomes and any imaging follow-up.

RESULTS: There were a total of 1037 discrepancies identified, of which 141 were due to intracranial hemorrhage. The most common types of intracranial hemorrhage that were missed were subdural and subarachnoid hemorrhage occurring in 39% and 33% of the cases, respectively. The most common location for missed subdural hemorrhage was either parafalcine or frontal. The most common location of missed subarachnoid hemorrhage was in the interpeduncular cistern. There was 1 case of nontraumatic subarachnoid hemorrhage that was not described in the preliminary report. Fourteen patients were brought back to the emergency department for short-term follow-up imaging after being discharged. We did not observe any adverse clinical outcomes that resulted from a discrepant reading.

CONCLUSION: Discrepancies due to intracranial hemorrhage are usually the result of subdural or subarachnoid hemorrhage. A more complete understanding of the locations of the missed hemorrhage can hopefully help decrease the discrepancy rate to help improve patient care.

Academic radiology departments are under increased pressure to provide 24-hour in-house attending coverage, inciting debates in the literature about the potential negative impact on radiology residency training of instituting this policy.[1-3] An argument for providing continuous in-house attending coverage is the presence of errors in preliminary interpretation of examinations by residents; however, the error rate for overnight preliminary interpretations by residents has been shown to be quite low.[4-8] CT examination of the head is the most frequently requested after-hours study and can account for up to 57% of all CT examinations performed on call.[9] The fear of being unable to detect intracranial hemorrhage among radiology residents at our institution was the impetus for our study. We report our experience with residents' preliminary interpretations given at night on head CT examinations specifically focusing on the patterns of missed intracranial hemorrhage and assess if there were any adverse clinical outcomes.

Materials and Methods

From January 1, 2002, to July 31, 2006, adult head CT examinations were prospectively interpreted by residents at night at an academic level I trauma center that has the largest neurosurgical intensive care unit in the area. The patient population included trauma and nontrauma patients seen in the emergency department as well as hospital inpatients. Head CT scans were interpreted from 5:00 PM to 7:00 AM by

second- through fourth-year residents who had at least 1 month of dedicated training in head CT interpretation. The training also included a series of core lectures in head CT interpretation, with emphasis on stroke and trauma, during a 6-month time period. Studies that were reviewed by staff via teleradiology were excluded from the study. Preliminary readings were communicated to the emergency department by fax or an electronically transcribed preliminary report and became a part of the patient's permanent medical record. Preliminary readings on inpatients were communicated to the ordering physician in a similar manner.

The CT scans were reviewed beginning at 7:00 AM the following morning by staff neuroradiologists, all being board-certified with a certificate of added qualification in neuroradiology and at least 10 years of experience in the field. Discrepancies were then documented in the final dictation of the report and communicated to the emergency department or the ordering in-house physician. Any case of hemorrhage that was not documented was counted as a discrepancy. For example, in a trauma patient with hemorrhagic contusions and subarachnoid hemorrhage described correctly on the preliminary report, an additional small tentorial subdural hematoma that was not mentioned and was not identified would be counted a discrepancy. In the same manner, having missed a left temporal hemorrhagic contusion in a patient with correctly reported bifrontal contusions would also count as a discrepancy. All discrepancies were reviewed and either confirmed or adjudicated by a single senior-level neuroradiologist (T.T.) with more than 20 years' experience in the interpretation of head CT examinations. Patient charts were reviewed for clinical outcomes and any imaging follow-up.

Results

Residents interpreted 22,590 head CT examinations overnight in the time period that was retrospectively reviewed. Of those

Table 1: Locations of subdural hemorrhage		
Location	Number	Total Number of Cases
Frontal		13
Right	8	
Left	5	
Parafalcine		13
Tentorial		10
Right	5	
Left	5	
Parietal		5
Right	4	
Left	1	
Other		3
Posterior fossa	2	
Anterior temporal	1	

Table 2: Locations of subarachnoid hemorrhage		
Location	Number	Total Number of Cases
Interpeduncular cistern		7
Sylvian fissure		5
Frontal		6
Left	4	
Right	2	
Diffuse		6
Parietal		5
Right	3	
Left	2	
Frontal/Parietal		4
Other		7

Table 3: Locations of contusions		
Location	Number	Total Number of Cases
Temporal		9
Right	5	
Left	4	
Frontal		9
Right	4	
Left	5	
Occipital		2
Right	1	
Left	1	
Parietal		2
Right	1	
Left	1	

examinations, there was a total of 1037 discrepancies (4.6% of resident-interpreted overnight examinations), 141 (13.6% of the total discrepancies, 0.62% of total resident-interpreted cases) of which were due to hemorrhage that was not included or was inaccurately described in the preliminary report. The most common indication given for the examination was trauma in 88 cases. Of the 141 discrepancies due to hemorrhage, in 28 instances, there were associated skull or facial fractures; and in 26 instances, there were other types of intracranial hemorrhage present that were correctly reported.

The most common pattern of hemorrhage that was incorrectly described in the preliminary report was subdural hemorrhage, of which 55 cases (39% of the discrepancies due to misidentified hemorrhage) were identified. A more detailed description of these findings appears in Table 1. Of these 55 cases, 8 (15%) cases were determined to be false-positives because the staff believed that the findings described by the residents were normal. Additionally, there were 2 instances in which the resident correctly described hemorrhage as being present but incorrectly described it as subdural rather than epidural hematoma (1 case) or subarachnoid hemorrhage (1 case).

The second most common pattern of hemorrhage that was incorrectly described in the preliminary report was subarachnoid hemorrhage, occurring in 46 cases (33% of the discrepancies due to misidentified hemorrhage). These findings are described in detail in Table 2. This included 2 cases of false-positives in which the resident incorrectly described hemorrhage as being present in the forth ventricle (1 case) and adjacent to the septum pellucidum (1 case), but the staff believed that the findings were normal. There were 4 cases of intraven-

tricular hemorrhage that were not described. Finally, there was 1 case of nontraumatic subarachnoid hemorrhage that was initially read as being significant only for hydrocephalus by the on-call resident. The patient was a 61-year-old woman who presented to the emergency department with mental-status change after recently using cocaine and marijuana, and she was admitted for further work-up, despite the preliminary interpretation. On follow-up imaging, less than 18 hours after the interpretation of the initial head CT examination, a left posterior inferior cerebellar artery aneurysm was documented, for which she was ultimately treated by surgical clipping that night.

The third most common pattern of hemorrhage that was incorrectly identified was intraparenchymal hemorrhagic contusion, which was observed in 22 (16% of the discrepancies due to misidentified hemorrhage) instances. These findings are represented in Table 3. There were no cases of false-positives due to contusion identified.

The fourth most common pattern of hemorrhage that was incorrectly described was punctuate hemorrhage or shear injury in 13 instances (9% of the discrepancies due to misidentified hemorrhage). This included 3 cases of false-positives in which shear injury was incorrectly identified in the left temporal region (1 case) or in the frontal white matter (2 cases). The most common locations that were not described were in the pons or midbrain (4 cases) or in the right frontal lobe (2 cases).

There was 1 case of an epidural hematoma that was not described on the preliminary report, and 1 case in which hemorrhage was described as an epidural hematoma when it was thought to be a subdural hematoma.

There were 3 cases of hemorrhage that could not be classified (2% of the discrepancies due to misidentified hemorrhage). Two cases of extra-axial blood in the middle cranial fossa were not identified by the resident; however, they could not be definitively labeled as either epidural or subdural hematoma by the staff. Finally, there was 1 case in which an existing parenchymal bleed in an inpatient had increased in size, but the resident thought it was unchanged.

Imaging follow-up was available in 75 cases and was usually performed in 24–48 hours. In 62 (83%) cases, the abnormality described by the staff neuroradiologist persisted; however, in 13 (17%) cases, the abnormality was not present on follow-up imaging. Although we cannot provide any scientific data to support the claim, we believe that dissipation of hem-

orrhage may partially account for the high number of cases in which the hemorrhage was not present on follow-up imaging.

On clinical follow-up of the discrepancies, there were 14 patients (10% of the total number of discrepancies due to misidentified hemorrhage) who were called back to the emergency department for additional imaging on the basis of the clinical suspicion of the emergency department physician and the symptoms of the patient on follow-up communication. The most common finding that resulted in a callback to the emergency department was subdural hematoma in 9 cases. Thirteen of the 14 patients were sent home the same day from the emergency department after there was no significant change on follow-up imaging. One patient, a 21-year-old who presented with head trauma, was admitted for observation because he was having increasing headaches despite little change in the appearance of contusions and decreased conspicuity of subarachnoid hemorrhage on follow-up imaging. Both the contusions and subarachnoid hemorrhage were not described in the preliminary report. Other than the patients having to return for follow-up imaging, we are not aware of any adverse clinical consequences of any of the other misinterpretations.

Discussion

Although the rate of disagreement between initial interpretations of CT scans of the head by emergency department physicians and the final interpretations by radiologists has been found to be nearly 39%,[10] with a large proportion of the misinterpretations being of clinical consequence,[11] the discrepancy rate of residents is much lower.[4-7] Erly et al[7] described the experience with 1324 residents' preliminary interpretations on head CT examinations and found a 2% major discrepancy rate and a 7% minor discrepancy rate. Major discrepancies included vasogenic edema misinterpreted as ischemia, a missed suprasellar mass, acute infarcts, and contusion. The most common minor discrepancies were missed facial fractures and chronic ischemic foci. In this study, higher level residents had greater accuracy in CT interpretation.

Wyoski et al[6] evaluated interpretation of 419 cranial CT studies by residents and found a major discrepancy rate of 1.7% and a minor discrepancy rate of 2.6%. Most major discrepancies involved subdural hematomas with no adverse clinical outcomes. Others included subarachnoid hemorrhage, contusion, and acute infarcts. The most common minor discrepancies in this study were missed skull and facial fractures.

One report specifically focused on the potential adverse clinical outcome of misinterpretation of head CT examinations by residents. Lal et al[5] found that in 2388 neuroradiologic scans, there was a 0.9% rate of significant misinterpretation by residents. However, they found that it was rare (0.08%) that a potentially serious effect on patient outcome resulted, where 2 cases of acute stroke were incorrectly triaged as a result of the preliminary interpretation.

In our study, we used staff neuroradiologists as the standard of reference; however, this was at times an imperfect gold standard. In 13 instances, the abnormality described by staff did not persist on follow-up imaging. Ultimately, we cannot provide any scientific evidence to support the claim that these represent true false-positives by staff or simply dissipated

hemorrhage. One study specifically focused on the performance of community radiologists. Erly et al[12] attempted to quantify the error rate of community radiologists; 716 consecutive CT scans of the head were interpreted by community radiologists and then compared with the readings of neuroradiologists. They found a 2% rate of significant disagreement, in which there were cases of overlooked subdural hematomas, acute infarction, contusions, subarachnoid hemorrhage, and suprasellar masses. The rate of insignificant disagreement was found to be 3%. Finally, the sensitivity and specificity for detecting acute stroke and intracranial hemorrhage among general radiologists were found to be similar to that of residents.

When compared with the prior studies in the literature, we observed many of the same types of discrepancies due to intracranial hemorrhage. Despite the fact that some of the patients had to return to the emergency department after being discharged, many of them were sent home after being evaluated on the same day. A single patient was admitted, not on the basis of his follow-up imaging but because his headaches were increasing. There was 1 patient who was admitted with cocaine intoxication with a nontraumatic subarachnoid hemorrhage, which was found to be from an aneurysm the following morning, who was admitted on the basis of her clinical disposition. Whether these findings on clinical follow-up can be considered to be adverse outcomes as a result of the residents not describing them on the preliminary report can be debated.

We could not account for the frequency of other on-call duties that residents routinely perform that may have resulted in increased distraction and affected the error rate. Our low error rate, compared with those rates reported for residents on body CT examinations, may be due to the smaller range of indications for head CT examinations, making their interpretation easier. We can offer no scientific explanation for why residents missed subdural or subarachnoid blood most frequently. The fact that the most commonly missed subdural hematomas were in the midline and along the tentorium is likely because it is harder to distinguish hemorrhage in these areas from the normal attenuated appearance of the falx and the tentorium. A diffuse pattern of subarachnoid hemorrhage was commonly misidentified, likely because it was symmetric and more challenging to perceive than an asymmetric pattern. Finally, the difficulty in identifying contusions could be explained by the inability to distinguish the hemorrhage from partial volume averaging with bone in the orbital roofs or in the middle cranial fossa.

Our study does have some limitations. First, noncompliance with completion of forms for documentation of discrepancy or agreement of what exactly constitutes a discrepancy could have affected our rate, though with such a large sample size, the effect may be nominal with the inclusion of a few additional studies. Furthermore, we do not have a true denominator of the total number of cases of hemorrhage that were identified correctly or the number of study findings that were simply normal.

Further studies will focus on other types of misinterpretations on head CT examinations, such as those related to ischemic change or fractures, in an effort to identify any repetitive patterns in these areas for educational purposes. For example, discrepancies from overnight cases can be gathered and shown to residents as a part of a quality assurance lecture series. Ad-

ditionally, a test can be given to residents using these cases before having them participate in overnight call.

Conclusion

We observed that discrepancies due to intracranial hemorrhage are usually because of subdural or subarachnoid hemorrhage. The significance of these findings can be debated because we did not observe a single adverse clinical outcome resulting from the discrepancies, but we acknowledge that a discrepancy in 1 case alone could have a horrific outcome for a patient.[4] Opponents of overnight head CT interpretation by residents do not acknowledge the inherent error rate in interpretation by board-certified radiologists and that the residents' readings are ultimately compared with the attendings' readings, which have been shown to be an imperfect clinical standard.[12] With a more complete understanding of misinterpretation of intracranial hemorrhage by residents, their education can be tailored to help decrease its frequency in the future and ultimately help improve patient care.

References

1. Strub W. **On-call resident preliminary reads: should the process continue?** *J Am Coll Radiol* 2005;2:1042
2. Bansal A. **On-call resident preliminary reads: should the process continue?** *J Am Coll Radiol* 2005;2:1043
3. Goradia D, Blackmore CC, Talner LB, et al. **Predicting radiology resident errors in diagnosis of cervical spine fractures.** *Acad Radiol* 2005;12:888–93
4. Strub WM, Vagal AA, Tomsik T, et al. **Overnight resident preliminary interpretations on CT examinations: should the process continue?** *Emerg Radiol* 2006;13:19–23
5. Lal NR, Murray UM, Eldevik O, et al. **Clinical consequences of misinterpretations of neuroradiologic CT scans by on-call radiology residents.** *AJNR Am J Neuroradiol* 2000;21:124–29
6. Wyoski MG, Nassar CJ, Koenigsberg RA, et al. **Head trauma: CT scan interpretation by radiology residents versus staff radiologists.** *Radiology* 1998;208:125–28
7. Erly WK, Berger WG, Krupinski E, et al. **Radiology resident evaluation of head CT scan orders in the emergency department.** *AJR Am J Roentgenol* 2002;23:103–07
8. Carney E, Kempf J, De Carvalho V, et al. **Preliminary interpretations of after-hours CT and sonography by radiology residents versus final interpretations by body imaging radiologists at a level I trauma center.** *AJR Am J Roentgenol* 2003;181:367–73
9. Scott JN, Romano CC. **On-call services provided by radiology residents in a university hospital environment.** *Can Assoc Radiol J* 2003;54:104–08
10. Alfaro D, Levitt MA, English DK, et al. **Accuracy of interpretation of cranial computed tomography scans in an emergency medicine residency program**. *Ann Emerg Med* 1995;25:169–74
11. Arendts G, Manovel A, Chai A. **Cranial CT interpretation by senior emergency department staff.** *Australas Radiol* 2004;47:368–74
12. Erly WK, Ashdown BC, Lucio RW, et al. **Evaluation of emergency CT scans of the head: is there a community standard?** *AJR Am J Roentgenol* 2003;180:1727–30