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MRI Versus CT for Identification and Quantification of Intraventricular Hemorrhage

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Abstract

Background—Intraventricular hemorrhage (IVH) may be difficult to detect especially when in small amounts, and may affect outcomes. The objective of this study was to compare the sensitivity of MRI versus CT for the identification and quantification of IVH.

Methods—Patients with primary intracerebral hemorrhage were enrolled into a prospective registry between December 2006 and June 2013. Diagnostic and surveillance neuroimaging studies were analyzed for the presence of IVH and quantified by Graeb score. In subjects who developed IVH and underwent both MRI and CT, each MRI was paired with the CT scan done at the closest time point, and Graeb scores were compared with the Wilcoxon signed rank test for related samples.

Results—There were 289 subjects in the cohort, with IVH found in 171. 68 pairs of MRI and CT were available for comparison. CT failed to detect IVH in 3% of cases, whereas MRI was 100% sensitive. MRI and CT yielded equal Graeb scores in 72% of pairs, and MRI Graeb score was higher in 24% ($p=0.007$).

Conclusion—MRI identifies small volumes of IVH in cases not detected by CT, and yields higher estimates of intraventricular blood volume. These data indicate that consideration of technical differences is needed when comparing images from the two modalities in the evaluation for IVH.

Keywords

MRI; magnetic resonance imaging; CT; computed tomography; intraventricular hemorrhage; intracerebral hemorrhage

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Introduction

Computed tomography (CT) and magnetic resonance imaging (MRI) are both routinely used to examine patients who have acute intracranial bleeding. While CT has been the standard modality to assess for hemorrhage, use of MRI has become increasingly prevalent as its blood detection accuracy has been confirmed for intracerebral hemorrhage (ICH).¹ Much less evidence exists regarding the sensitivity of MRI for detecting and quantifying intraventricular hemorrhage (IVH). Extent of IVH, delayed IVH and IVH growth have all been shown to affect functional outcomes after ICH, so accurate detection and quantification of IVH is critical for patient care as well as uniformity of clinical study methodology.²⁻⁴ The objective of this study is to compare the sensitivity of MRI versus CT for the identification and quantification of IVH.

Methods

Patients

Consecutive patients presenting to Northwestern Memorial Hospital with spontaneous ICH between December 2006 and May 2013 were prospectively enrolled in an observational cohort study. Patients with ICH attributed to trauma, hemorrhagic conversion of ischemic stroke, structural lesions or vascular malformations were excluded for the sake of cohort uniformity and generalizability of study results. The study was approved by the Institutional Review Board (IRB). Written informed consent was obtained from the patient or their legally authorized representative during the index hospitalization, as soon as feasible. The IRB approved a waiver of consent for patients who died during initial hospitalization, or who were incapacitated and for whom a legal representative could not be located.

Imaging Protocol

Diagnostic and surveillance neuroimaging was obtained by institutional protocol, as we have previously published.⁵ All imaging was obtained for clinical care at the discretion of the treating team. CT imaging was obtained on 16- or 64-slice Siemens scanners. MR imaging was obtained whenever feasible in salvageable patients (those deemed unlikely to die within 48 hours from ICH symptom onset) on Siemens 1.5-T MR scanners (Siemens AG). The MR protocol included unenhanced sagittal and axial T1, axial gradient echo, axial FLAIR and T2 TSE, axial DWI and ADC. Unenhanced sagittal and axial T1 images were acquired with a TR of 450 ms, effective TE of 20 ms, FOV of 20 cm, image matrix of 512 × 512 pixels, section thickness 5-mm with a 1.5-mm gap. Gradient echo images were acquired with a single-echo sequence, a TR of 806 ms, TE of 25 ms, a flip angle of 20 degrees, a 20 cm FOV, a 512 × 448 pixel image matrix, section thickness 5-mm with a 1.5-mm gap. FLAIR images were acquired with a TR of 9002 ms, effective TE of 138 ms, an FOV of 20 cm, image matrix of 512 × 512 pixels, section thickness 5-mm with a 1.5-mm gap. Turbo spin-echo T2WI was acquired with a TR of 5700 ms, effective TE of 110 ms, FOV of 20 cm, image matrix of 512 × 512 pixels, section thickness of 5-mm with a 1.5-mm gap. DWI was obtained by using single-shot echo-planar imaging with sampling of the entire diffusion tensor. Six high-b-value images corresponding to diffusion measurements in different gradient directions were acquired followed by a single low-b-value image. The high b-value

was 1000 s/mm², and the low b-value was 0 seconds/mm². Imaging parameters were a TR of 5 seconds, a TE of 90 ms, an FOV of 22 × 22 cm, image matrix of 192 × 192 pixels, section thickness of 5-mm with a 1.5-mm gap, 23 axial sections, 5 signal intensity averages.

Imaging Evaluation

Each neuroimaging study obtained during the initial hospitalization was prospectively reviewed by a board certified neuroradiologist, and then retrospectively confirmed by a board certified neurointensivist (M.B.M.) with experience in research imaging analysis and a trained imaging analyst (A.L.R.), to identify the appearance of IVH on DWI, FLAIR, T2WI, T1WI, and gradient echo images, quantified by Graeb score.⁶ Prior studies have found that an imaging interpretation that combines impressions from multiple sequences achieves the highest sensitivity and specificity, so we utilized a composite evaluation.^{7, 8} Scan readers were blinded to all clinical information other than the contents of the imaging study they were reading. The Graeb score, an uncomplicated assessment with scores ranging from 0 to 12, has been found to perform equivalently to the IVH score and LeRoux score in assessing IVH severity and risk-stratifying ICH patients with regard to outcome.² The Graeb scoring method is summarized in Table 1. We tested whether MRI identified greater extent of IVH by comparing the Graeb scores of each MRI paired with Graeb scores from the CT done at the nearest time to it using the Wilcoxon signed rank test for related samples, and the inter-method agreement between MRI and CT was determined by intraclass correlation coefficient. To eliminate the possibility of confounding by hematoma growth, we repeated the same analysis by pairing the MRI scan with the closest preceding and subsequent CT scans.

Results

The consent rate for study enrollment was 95%, resulting in a cohort of 289 subjects. IVH was found in 139 (48.1%) subjects on initial imaging, and delayed IVH in an additional 32 (11.1%) subjects. There were 68 pairs of MRI and CT available for comparison from 63 separate subjects. A diagram of case selection and imaging results is shown in Figure 1, and the clinical characteristics of these patients are summarized in Table 2. The diagnosis of IVH was missed on CT in 2 (3%) of the 63 cases, where CT studies both before and after the positive MRI were negative. There were no cases of failed IVH detection by MRI.

The median time difference between the paired scans was 6.0 hours (2.4-9.3 hr), and the median time between symptom onset and the MRI scan of the pair was 30.9 hours (17.9-55.2 hr). For 46 patients the closest CT preceded the MRI, and followed the MRI in 22 patients. The median Graeb score of the scan pairs was 3 (interquartile range 2-6) for both MRI and CT. The MRI and CT agreed on Graeb score in 49 (72%) of the pairs, MRI identified more extensive IVH in 16 (24%), and CT found more extensive IVH in 3 (4%, $p=0.007$ by Wilcoxon signed rank test). Example slices from three sets of CT and MRI pairs are shown in Figure 2, where MRI in each instance better demonstrates the presence of ventricular blood. Most differences were low magnitude with only five Graeb scores differing by >1 point, weighted intraclass correlation was excellent (ICC 0.95, $p<0.001$). Repeating the analysis by pairing the MRI scans with either the preceding or subsequent

CT yielded nearly identical results, with MRI Graeb scores consistently higher ($p=0.016$ and $p=0.003$ respectively).

Discussion

The data presented here identify MRI as a more sensitive modality for IVH detection, and indicate that careful interpretation is needed when comparing intraventricular hematoma volume between the two modalities. CT imaging missed the diagnosis of IVH in 3% of subjects, and yielded lower estimates of intraventricular blood volume than MRI.

Current guidelines recommend either CT or MRI for diagnostic imaging, and serial surveillance neuroimaging with either nonenhanced CT or rapid acquisition MRI is frequently used to monitor patients for important clinical changes.^{5, 9} IVH is a strong predictor of outcomes in patients with ICH, and is used as a risk adjuster for poor outcomes in common scales of disease severity.^{10, 11} Unequal sensitivity between imaging modalities can misjudge IVH incidence, IVH extent, and IVH growth.

Two small case series have compared the reliability of MRI against CT, both using CT as the gold standard. One reported series of 22 patients with a mean 22 hours between scans, and another series of 11 patients with a mean 36 hours between scans, and found that the sensitivity of different MRI sequences ranged from 77% to 100% for IVH detection, with 100% specificity.^{7, 8} Both of these series found that the sensitivity of MRI combining standard sequences was 100% with CT as the gold standard, but no research had evaluated the possibility of MRI having superior sensitivity.

A few potential limitations are worth noting. First, there is no gold standard measure against which the IVH quantification by MRI and CT can be compared. MRI derived Graeb scores may be higher because of better sensitivity for detection of blood products, as has been reported for ICH and was seen here in two cases that were not detected by CT.¹ Alternatively, susceptibility artifacts may exaggerate the extent of blood present.¹² Given that no other pathologic processes were active that could mimic IVH, and earlier studies findings that MRI was 100% specific for intraventricular blood, bias driven by false-positive MRI findings is unlikely. Second, compared scans were not performed simultaneously, introducing the possibility that IVH growth and delayed IVH may confound the comparison because the MRI was more often the second scan of the pair.^{3, 4} We resolved this potential confounder by repeating the analysis and pairing each MRI with the closest preceding and subsequent CT scans to confirm our results. Further, the median time between symptom onset and MRI was over 30 hours, far beyond the hematoma expansion timeframe. Third, MRI was not performed in every subject and was usually performed only once, so additional instances of failed IVH detection by CT may have gone unrecognized. In comparison to prior reports, this study evaluated more than three times the number of scans and used more contemporary CT technology, with a much shorter time interval between comparison scans, and avoided the assumption that CT is 100% sensitive. Further, our imaging analysis did not analyze each MRI sequence independently and blinded from the other sequences in such a way that individual sequences could be compared against each other and CT. That analysis has been reported on smaller cohorts.^{7, 8} Instead, we sought to assess the usual clinical

practice where different MRI sequences are read together and cross referenced to optimize the interpretation, which we believe to be more relevant to actual routine practice. Finally, the clinical impact of small volume IVH that may be undetectable by CT is unknown and will require further study.

Conclusion

MRI was found to be more sensitive to the presence of IVH than CT, and yielded higher quantitative measures of intraventricular hematoma volume in a large cohort of patients undergoing evaluation of acute intracerebral hemorrhage. Awareness of this difference between modalities when comparing CT and MRI may help to interpret findings.

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Figure 1.
Study Design and Analysis

Figure 2.

Example of Paired CT and MRI Images for Subjects with IVH Panels 1A and 1B: CT and MRI-GRE sequence of a left lentiform nucleus hemorrhage. IVH in the left lateral ventricle is better demonstrated by MRI. Panels 2A and 2B: CT and MRI-FLAIR sequence of a right lentiform nucleus hemorrhage. IVH in the occipital horns of both lateral ventricles is detected to much greater advantage by MRI. The CT is interpreted as not demonstrating intraventricular hemorrhage. Panels 3A and 3B: CT and MRI-GRE sequence of a supratentorial hemorrhage. IVH on the floor of the fourth ventricle is better detected by MRI. Again, the CT is interpreted as not demonstrating intraventricular hemorrhage.

Table 1**Graeb Score for Intraventricular Hemorrhage Quantification**

Each Lateral Ventricle	Third and Fourth Ventricles
0- no blood	0- no blood
1- trace blood	1- blood present, ventricle size normal
2- <50% filled with blood	2- filled with blood and expanded in size
3- >50% filled with blood	
4- completely filled with blood and expanded in size	

The total score ranges from 0 (no intraventricular hemorrhage) to 12 (each of the four ventricles filled with blood and expanded).

Table 2

Patient Characteristics

Age (mean, SD)	63.1 ($\pm$ 12.9)
Male sex (n, %)	34 (50%)
Race	
White (n, %)	30 (44%)
Black (n, %)	31 (46%)
Other (n, %)	7 (10%)
Admission GCS (median, IQR)	14 (8.75-14.25)
ICH volume (median, IQR)	12 (5-24.25)
ICH location	
Lobar (n, %)	21 (31%)
Deep (n, %)	42 (62%)
Cerebellar/brainstem (n, %)	5 (7%)
Graeb Score (median, IQR)	3 (2-6)
Graeb disagreement (n, %)	19 (28%)

GCS- Glasgow Coma Scale score, ICH- intracerebral hemorrhage, IQR- interquartile range, SD- standard deviation