

Computed Tomographic Angiography and Venography for Young or Nonhypertensive Patients With Acute Spontaneous Intracerebral Hemorrhage

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Background and Purpose—We compared the effectiveness of using computed tomographic angiography and venography (CTAV) with digital subtraction angiography (DSA) in young or nonhypertensive patients with acute spontaneous intracerebral hemorrhage.

Methods—We prospectively recruited 109 young (age between 18 and 45 years) or nonhypertensive patients with acute spontaneous intracerebral hemorrhage for this comparative study. All patients had CTAV using multidetector CT with 64 detectors. They were then scheduled to have catheter angiography the next day. Radiological data were collected for blinded analysis.

Results—DSA-positive pathologies causing hemorrhage were identified in 37 (33%) patients, which included cerebral arteriovenous malformation in 22 cases. The positive and negative predictive values of CTAV for DSA-positive pathologies causing hemorrhage were 97.3% (95% CI, 88.3%–99.9%) and 100% (95% CI, 95.9%–100%), respectively.

Conclusions—CTAV was able to detect DSA-positive pathologies causing acute spontaneous intracerebral hemorrhage in young (age between 18 and 45 years) or nonhypertensive patients with high positive and negative predictive values. (*Stroke*. 2011;42:211–213.)

Key Words: arteriovenous malformation ■ cerebral angiography ■ computed tomography ■ intracerebral hemorrhage ■ stroke

One of the major management tasks in spontaneous intracerebral hemorrhage is to find out whether the hemorrhage is secondary to an underlying structural vascular abnormality, such as arteriovenous malformation, aneurysm, or sinus thrombosis. Computed tomography angiography and venography (CTAV) has the multiple advantages of being a quick procedure (only minutes using multidetector row CT), noninvasive, more readily available, and advantageous for agitated or confused patients.^{1–4} It is thus important to assess and establish the roles of these techniques in a protocol setting. We aimed to compare the effectiveness of using CTAV with digital subtraction angiography (DSA) in young or nonhypertensive patients with acute spontaneous intracerebral hemorrhage by showing that a good-quality CTAV has high positive and negative predictive values.

Subjects and Methods

We recruited consecutive patients with spontaneous nonhypertensive and/or lobar intracerebral hemorrhage who presented within 96 hours after the initial ictus for the study. In accordance with our published data

in the literature, we investigated for underlying vascular malformation in these patients, except among those older than 45 years with preexisting hypertension and thalamic, putaminal, or posterior fossa hemorrhage.⁵ In the current study, we also excluded patients 70 years old or older and those with known renal impairment or allergy to intravenous contrast, or with emergency craniotomy before DSA. Informed consent was obtained from patients or next of kin. Patients were scheduled for CTAV within 24 hours after admission and a catheter angiography within 48 hours after admission. For the purpose of recruitment, hypertensive patients were defined as such by either their medical history or evidence of chronic hypertension (cardiomegaly on chest x-ray and/or left ventricular hypertrophy on electrocardiography).

Protocols for CTAV and DSA were described in the Supplemental Appendix (available online at <http://stroke.ahajournals.org>) If the CTAV and DSA images were normal, then following our current clinical routine, a second catheter angiography and/or MRI were arranged 6 to 12 weeks later (at the time the hematoma resolved) to determine whether an underlying arteriovenous malformation, cavernoma, aneurysm, or tumor existed that may have been masked by the initial hemorrhage. Cavernoma accounted for hemorrhage in 8% of patients.⁶

Main Outcome Measures

For data acquisition, the CT data (CTA, CTV, contrast CT) were reviewed separately by 2 neuroradiologists blinded to the clinical

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data and catheter angiography findings, and the catheter angiography data were reviewed by an interventional radiologist and an endovascular neurosurgeon separately blinded to the clinical and the CT data (CTA, CTV, contrast CT). Differences in opinion were resolved by discussion between the 2 observers and all differences were resolved by consensus after discussion. A positive finding was defined as one in which the underlying vascular etiology for the intracerebral hemorrhage was identified or suspected.

Statistical Analysis

Vascular lesions were assessed by both CTAV and catheter angiography, in which catheter angiography served as comparison. From the analysis, we determined the CTAV predictive values for DSA-positive pathologies (sensitivity, specificity, accuracy, positive predictive value, and negative predictive value). Intermodality agreement for DSA-positive pathologies and cerebral arteriovenous malformations were assessed using Cohen κ coefficient. Data analysis was performed using SPSS for Windows version 15.0. A difference with $P < 0.05$ was regarded as statistically significant (2-tailed test).

Results

We screened a total of 966 patients with spontaneous intracerebral hemorrhage over a 3-year period from January 1, 2007 to December 31, 2009. Exclusion criteria included age older than 70 years (406 patients), emergency craniotomy before DSA (156 patients), and typical hypertensive deep-seated hemorrhage patients aged older than 45 years (269 patients). In total, 135 patients were eligible, and 109 (81%) of them consented to participate in the current study. The mean (\pm SD) age of participants was 47.6 (\pm 14.9) years, and 73 (67%) were male. Hematomas were of the following types, based on location: lobar (80; 73%), putaminal (17; 16%), thalamic (3; 3%), cerebellar (7; 6%), and brain stem (2; 2%). The mean (\pm SD) intracerebral hematoma volume was 19.2 (\pm 21.7) mL. Associated hemorrhages included subdural (18; 17%), focal subarachnoid (42; 39%), and intraventricular (37; 34%) ones.

DSA-positive pathologies causing hemorrhage were identified among 37 (33%) patients, which included cerebral arteriovenous malformation (22; 20%), cerebral aneurysm (2; 2%), sinus thrombosis (7; 6%), and brain tumor (2; 2%). All of the vascular lesions were also identified via CTAV. CTAV made a false-positive diagnosis of a cerebral arteriovenous malformation, which turned out to be a venous angioma on DSA. Thus, CTAV to detect DSA-positive pathologies had accuracy, positive predictive value, and negative predictive value of 99.1% (95% CI, 95.7%–100%), 97.3% (95% CI, 88.3%–99.9%), and 100% (95% CI, 95.9%–100%), respectively (Table). Cohen's κ coefficients were 0.98 ($P < 0.001$) and 0.97 ($P < 0.001$) for DSA-positive pathologies and cerebral arteriovenous malformations, respectively, which indicate excellent intermodality agreement.

For cerebral arteriovenous malformations, DSA identified 29 arterial feeder origins and 29 venous sinus/deep venous drainage systems, among which 28 (97%) arterial feeder origins and 24 (83%) venous sinus/deep venous drainage systems were identified via CTAV. Cohen κ coefficients for the identification of arterial feeder origins and venous sinus/deep drainage systems were 0.94 ($P < 0.001$) and 0.78 ($P < 0.001$), respectively, indicating excellent and good intermodality agreements. Five (22.7%) cerebral arteriovenous

Table. Diagnostic Accuracy of Multidetector CT Angiography and Venography in Spontaneous Intracerebral Hemorrhage

Findings	DSA Confirmed Related Vascular Lesions	DSA Confirmed No Related Vascular Lesions	Total
Positive CTAV	37	1	38
Negative CTAV	0	71	71
Total	37	72	
Sensitivity	100% (95% CI, 92.4%–100%)		
Specificity	98.6% (95% CI, 93.6%–99.9%)		
Accuracy	99.1% (95% CI, 95.7%–100%)		
Positive predictive value	97.3% (95% CI, 88.3%–99.9%)		
Negative predictive value	100% (95% CI, 95.9%–100%)		

CTAV indicates computed tomography angiography and venography; DSA, digital subtraction angiography.

malformations had nidal aneurysms on DSA, whereas 11 (50%) cerebral arteriovenous malformations had nidal aneurysms on CTAV. Cohen κ coefficient for nidal aneurysms was 0.455 ($P = 0.011$), which indicates only fair intermodality agreement.

Discussion

We were able to show that CTAV has high positive and negative predictive values for vascular pathologies (DSA-positive) in young (age between 18 and 45 years) or nonhypertensive patients with acute spontaneous intracerebral hemorrhage. CTAV could serve as a screening tool for arteriovenous malformation before emergency hematoma evacuation in neurologically deteriorating patients; however, for the assessment of the angioarchitecture (venous drainage and nidal aneurysm) of arteriovenous malformation, CTAV is still deficient compared to DSA.

A recent systemic review and survey investigated the diversity in protocols for the radiological investigation of spontaneous nontraumatic intracerebral hemorrhage.⁷ Such diversity is probably attributable to uncertainty regarding the predictive values of noninvasive imaging and risk of DSA. The results of the current study show that CTAV for the noninvasive investigation of vascular lesions has high predictive values in detecting vascular pathologies and is applicable during the acute phase. Thus, it could be the target of future studies of the diagnostic yield for acute spontaneous hypertensive intracerebral hemorrhage and act as a cornerstone for future radiological investigative protocols for patients with spontaneous intracerebral hemorrhage. One important point is that we only included young or nonhypertensive patients and, thus, the reported diagnostic yield should not be generalized to all hemorrhagic stroke patients.

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Disclosures

None.

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Supplemental Material

Study Instruments

CTAV was carried out with 64-slice CT software and hardware (GE Healthcare, US). We first performed a pre-contrast CT scan of the whole brain, axial mode 120 kV 340 mAs, tilted along the occipito-meatal line. For adult patients, CTAV was carried out with intravenous contrast injection (100 ml Omnipaque 300, 3 ml/s) using a power injector via an 18 gauge catheter typically positioned in the antecubital vein. For pediatric patients, Visipaque 270 2 ml/kg was used. CTAV covered the volume from the foramen magnum to the vertex. Arteriography was carried out by scanning of the whole brain at delay (from the start of intravenous contrast injection) with the assistance of the bolus tracking software SmartPrep (GE Healthcare, US) and monitoring of the petrous internal carotid artery. Venography was performed with scanning of the whole brain at a 60 s delay from the start of intravenous contrast injection. Both arteriography and venography were performed in helical mode 120 kV 220 mAs with no tilting. We completed the imaging with a post-contrast CT scan of the whole brain with the same setting as the pre-contrast scan. Axial images were reconstructed at 0.625 mm intervals and stored as source images for further image analysis with three-dimensional (3D) reconstruction. Standard multiplanar reformation and maximum intensity projection images of the major intracranial vessels were also created and reviewed.

For volume calculation, we employed the ellipsoid model following Kothari et al. [1]. In brief, all slices with a lesion volume less than 25% of the slice with the maximum lesion volume were not counted in the z axis; for slices in which the lesion volume was between 25% to 75%, the slice thickness was multiplied by 0.5, and for slices where the

lesion volume was more than 75%, the slice thickness was multiplied by 1. π was simplified to 3 for calculation, and thus the formula is $ABC/2$, where A is equal to the longest dimension along the x axis, B is equal to the longest dimension perpendicular to the x(y) axis and C equals the corrected total slice thickness in the z dimension.

Catheter angiography (DSA) was carried out through the femoral transarterial approach using the standard Seldinger technique, with biplane digital subtraction angiography. The primary diagnostic catheter was the Headhunter (H1) catheter. Biplane digital subtraction angiography was performed with the Philips V3000 DSA unit (Philips, BG Eindhoven, Netherlands). Depending on the location of the intracerebral hemorrhage, relevant cervical vessels were catheterized for angiography. For example, for a left parieto-occipital hemorrhage, the left internal carotid artery, left external carotid artery and left vertebral artery were selected for study. Standard views were obtained by hand injection of Omnipaque 300 6-9 ml and 3D angiography was performed for patients with vascular lesions noted on the standard views. Cerebral arteriovenous malformation and dural arteriovenous fistula were diagnosed by their nidus location, early draining vein and sinus abnormality.

The parameters for assessment included the intracerebral hematoma characteristics, presence and characteristics of vascular malformation, presence of intracranial aneurysm, presence of sinus thrombosis and presence of other vascular lesions. Cerebral arteriovenous malformations were examined for the origin of the arterial feeder (internal carotid artery, posterior communicating artery, anterior choroidal artery, anterior cerebral artery, middle cerebral artery, posterior cerebral artery, vertebral artery, basilar artery, superior cerebellar artery, anterior inferior cerebellar artery, posterior inferior cerebellar

artery) and venous sinus/deep venous drainage system (superior sagittal sinus, transverse sinus, sigmoid sinus, straight sinus, vein of Galen, internal cerebral vein, basal vein of Rosenthal, cavernous sinus, sphenoparietal sinus).

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