Vertebral Artery Injury After Acute Cervical Spine Trauma: Rate of Occurrence as Detected by MR Angiography and Assessment of Clinical Consequences

OBJECTIVE. The purposes of this study were to assess prospectively the frequency of vertebral artery injuries after major acute cervical spine trauma as determined by MR angiography and to assess the clinical consequences of these injuries.

SUBJECTS AND METHODS. During a 6-month period, 37 patients who had major acute nonpenetrating cervical spine trauma were examined with MR imaging, usually within 24 hr of the injury. Routine spin-echo and gradient-echo images were supplemented by two-dimensional time-of-flight MR angiography of the extracranial head and neck vessels. The vertebral arteries were independently assessed by two neuroradiologists for nonvisualization, focal narrowing, or focal widening. Two patients had conventional angiographic correlation. The medical records of these 37 patients were also reviewed to determine the type of spinal injury, neurologic deficit on admission, and evidence of an intracranial neurologic deficit due to vertebral artery injury. The MR angiograms of 37 control subjects were interpreted to help determine the specificity of MR angiography; these studies were assessed only for the presence or absence of the vertebral arteries.

RESULTS. Findings on MR angiograms were abnormal in nine patients (24%). In seven cases, one vertebral artery was diagnosed as nonvisualized (occluded) or focally narrowed; one patient had bilateral vertebral artery injuries; and one patient had nonvisualization of the left common carotid and left vertebral arteries. In all 37 control subjects, both vertebral arteries were identified on MR angiograms. A significant difference in the frequency of vertebral artery nonvisualization (occlusion) was found between the trauma and control populations. The patient with bilateral vertebral artery injuries died 2 days after hospital admission of a massive infarction of the right cerebellar hemisphere. The other eight patients with vertebral artery injuries, and the remaining 28 patients with normal findings on MR angiograms, had no intracranial neurologic deficits that could be ascribed to a major arterial injury.

CONCLUSION. In our experience, vertebral artery injuries due to major cervical spine trauma as determined by MR angiography are common. Although these vascular abnormalities usually remain clinically occult, a small percentage of patients may suffer devastating neurologic complications of posterior fossa infarction. Noninvasive assessment of the vertebral arteries by means of MR imaging should be an integral part of the evaluation of the acutely injured cervical spine.

MR imaging is extremely helpful in the examination of patients with acute blunt injuries of the cervical spine [1, 2]. The imaging protocol is designed to detect cord hemorrhage and edema, disk herniation, ligamentous and osseous disruption, and epidural fluid. However, extracranial vertebral artery injury in these patients (e.g., occlusion, dissection, pseudoaneurysm formation) may cause devastating intracranial neurologic complications [3-9]. In previous studies [3-9], vertebral artery injuries have been identified retrospectively by using conventional angiography in symptomatic patients with ascending neurologic deficits. To our knowledge, no study has prospectively used MR angiography to evaluate the extracranial portions of the vertebral arteries in patients with acute cervical spine trauma.
Accordingly, we did a prospective study to determine the frequency of vertebral artery injuries as detected by MR angiography in 37 patients with acute cervical trauma. We also assessed the clinical course of these patients to estimate the frequency of symptomatic vertebral artery abnormalities.

Subjects and Methods

During the 6-month study period (March 1993 to August 1993), 42 patients admitted to our regional spinal cord injury center sustained nonpenetrating major cervical spine trauma (fracture, dislocation, hyperflexion, or hyperextension injury), diagnosed on the basis of clinical findings and/or findings on plain radiographs. All patients had MR imaging, including MR angiography, usually within 24 hr of admission but never later than 3 days after admission. In five patients, MR angiograms of diagnostic quality could not be obtained; this was usually because of inadequate coil placement or failure to complete the examination. Hence, 37 patients were included in the study (30 men, 7 women; 15–70 years old; mean age, 42 years).

At our institution, patients with major cervical spine trauma are fitted with an MR-compatible graphite halo (PMT; Chanhassen, MN) and scanned on a 1.5-T magnet. We use either a posterior neck coil or a 5-in. surface coil and routinely obtain T1-weighted spin-echo (e.g., 450/12/2 [TR/TE/excitations]) and dual-echo fast spin-echo (e.g., 2400–3000/17, 85/4, echo train lengths of 4 and 8, respectively) sagittal images. In addition, multiplanar gradient-recalled echo sagittal (e.g., 300/13/4, 10° flip angle) and axial (e.g., 35/15/2, 5° flip angle) images are obtained.

For this study, we added a two-dimensional time-of-flight (2D TOF) (e.g., 45/8.7, 60° flip angle, 18-cm field of view) MR angiogram of the extracranial head and neck vessels to our cervical spine trauma protocol. A walking saturation pulse was applied superiorly to suppress venous inflow signal. The stack of images was 13.5 cm in height (90 slices x 1.5 mm per slice) and was sufficient to evaluate the V2 and V3 segments of the vertebral arteries; the V1 (proximal) segments were not adequately assessed. The time of acquisition for the MR angiograms varied from approximately 6 to 9 min. The raw data sets were reconstructed by using a maximum-intensity-projection (MIP) algorithm. Nineteen projection images with angles in increments of approximately 10°, as well as a collapsed axial image, were displayed on film for interpretation. Additional MIP images were obtained in selected patients by manually isolating the vertebral arteries (Interactive Vascular Imaging, GE Medical Systems; Milwaukee, WI); this facilitated analysis by eliminating overlap from the carotid arterial systems. The raw data sets were analyzed in conjunction with the MIP images. The MR angiograms were independently interpreted by two neuroradiologists who were aware of the clinical status of the patient and the results of the cervical spine radiographs and/or CT scans. To minimize false-positive interpretations, studies were considered to show abnormal findings only if both neuroradiologists were independently in agreement.

On the MR angiograms of the 37 study patients, the vertebral arteries were assessed for (1) nonvisualization (indicating occlusion), (2) luminal narrowing (indicating focal spasm or dissection), and (3) increase in external diameter (indicating subintimal/ intramural hematoma or pseudoaneurysm formation). Luminal narrowing or increase in external diameter was required to be at least 25% of the diameter of the vessel, and it had to be located within one vertebral segment of the spinal injury and/or neurologic level. Moreover, it had to be identified on multiple projection images for the findings in that study to be considered abnormal.

Prospective conventional angiography was not routinely used in this study. Correlative conventional angiograms were obtained in two patients with abnormal findings on MR angiograms. Our control population consisted of 37 randomly selected patients without a history of trauma or proved diffuse atherosclerotic disease who had MR angiograms of the neck during the 6-month study period. The primary indication for examination in the control population was to assess for carotid stenosis; therefore, this population was composed of older patients. The control group consisted of 16 men and 21 women 22–75 years old (mean age, 59 years). The MR angiograms of the control subjects were independently assessed by two neuroradiologists only for the presence or absence of the vertebral arteries. Results of a control examination were considered abnormal only if both neuroradiologists were independently in agreement.

The degree of prereduction subluxation, if present, in each patient was determined by a review of plain radiographs or reports of outside studies. Clinical data obtained for each patient included the age, sex, type of spinal injury, neurologic deficit on admission, evidence of an intracranial neurologic deficit due to a vertebral artery injury, and change in clinical management based on abnormal MR angiographic findings.

Results

Abnormal findings on MR angiograms were present in nine (24%) of the 37 trauma patients; 11 vessels were identified as abnormal. In five patients there was nonvisualization of one vertebral artery (Fig. 1); in one patient there was nonvisualization of the left vertebral artery and focal narrowing of the right vertebral artery (Fig. 2); in one patient there was nonvisualization of the left vertebral and left common carotid arteries (Fig. 3); and in two patients there was focal narrowing of one vertebral artery (Fig. 4). In all 37 control subjects, both vertebral arteries were identified on MR angiograms. Nonvisualization (occlusion) of a vertebral artery was present in 19% of trauma patients but in none of the control subjects; this difference was statistically significant (p = .006; Fisher's exact probability test).

Twelve of the 37 trauma patients had complete motor and sensory deficits at admission; in six of these patients findings on MR angiograms were abnormal. Arterial injury was present in 50% of all patients with complete motor and sensory lesions, compared with 12% of patients with incomplete injuries. A significant correlation was found between the presence of a complete injury and the presence of an arterial injury.
Fig. 2.—Bilateral vertebral artery injury in 28-year-old man with complete motor and sensory lesion due to a severe C5-C6 hyperflexion injury with multiple fractures.
A. Axial CT scan (bone algorithm) of C5 vertebral body shows fracture involving left foramen transversarium (curved arrows). Fracture through right foramen transversarium (straight arrows) was better visualized on adjacent section.
B. Frontal oblique view, two-dimensional time-of-flight MR angiogram reveals nonvisualization of left vertebral artery. Right vertebral artery shows focal irregularity and narrowing (curved arrow) at level of injury; this was identified on multiple projections and is consistent with dissection or spasm. Reduced flow-related enhancement in V3 segment of right vertebral artery (straight arrows) is related to in-plane flow.
C. Lateral view, two-dimensional time-of-flight MR angiogram again shows focal narrowing (large arrow) of right vertebral artery (small arrows) at level of injury. Left vertebral artery is not visualized.
D. Axial cranial CT scan obtained 2 days after admission shows large infarction (arrows) in right superior cerebellar artery (SCA) territory. Basal cisterns are obliterated, and lateral and third ventricles are dilated. More caudal section (not shown) showed large infarction of right posterior inferior cerebellar artery (PICA) territory with compression of fourth ventricle. No other abnormalities were identified on the CT scan. As PICA is a branch of the vertebral artery, the presence of right PICA infarction supports diagnosis of right vertebral artery dissection. As right SCA is a branch of the basilar artery, right SCA infarction could be related to either vertebral artery injury. Patient died shortly after CT scan was obtained.

abnormality (p < .02; chi-square test). Thirteen of the 37 trauma patients had prereduction subluxations greater than 3 mm; in five of these patients, findings on MR angiograms were abnormal. Although arterial injury was seen in a greater proportion of patients with subluxations greater than 3 mm (38%) than in patients without subluxations or with subluxations less than 3 mm (17%), these differences were not statistically significant (p = .14; chi-square test).

Fig. 3.—Unilateral vertebral and common carotid artery occlusion in 48-year-old man with a complete motor and sensory lesion after a severe crush injury that resulted in multiple fractures of cervical spine. Frontal oblique view, two-dimensional time-of-flight MR angiogram reveals nonvisualization of left common, internal, and external carotid arteries, as well as left vertebral artery. Right internal carotid artery (small arrows) and right vertebral artery (large arrows) appear normal. Findings were identical to those on conventional angiograms (not shown). Systemic anticoagulation was begun 2 days later; no neurologic complications developed from these arterial occlusions or from anticoagulant therapy.

Fig. 4.—Unilateral vertebral artery injury in 44-year-old man with a complete motor and sensory lesion due to a C3-C4 fracture-dislocation. Frontal oblique view, two-dimensional time-of-flight MR angiogram shows focal irregularity and narrowing (curved arrow) of right vertebral artery (RVA) at level of C3; this was identified on multiple projections and is consistent with dissection or spasm. Left vertebral artery (LVA) and common carotid arteries (CCA) are identified.
The patient with bilateral vertebral artery injuries (Fig. 2) died of massive infarction of the right cerebellar hemisphere. The remaining 36 patients, including eight with arterial injuries, had no intracranial neurologic deficit that could be ascribed to a vascular lesion. One patient with arterial injuries and intramedullary hemorrhage (Fig. 3) was treated with systemic anticoagulation. The remaining eight patients in whom MR angiographic findings were abnormal had no change in their medical or surgical management.

Discussion

In previous studies [3–9], vertebral artery injuries have been identified retrospectively by using conventional angiography in symptomatic trauma patients with ascending neurologic deficits. Many asymptomatic lesions undoubtedly escape detection. A recent study (Greiner FG et al., presented at the 29th Annual Meeting of the American Society of Neuroradiology, June 1991) that used prospective conventional angiography showed a greater than 40% prevalence of vertebral artery injury in the setting of cervical spine fracture. Clearly, a good screening test to identify asymptomatic vertebral artery lesions in patients at risk would be invaluable. Because the carotid arteries are usually not affected in cases of cervical spine trauma, we chose not to systemically evaluate those vessels on the MR angiogram.

MR imaging and MR angiography are noninvasive techniques that can be used to evaluate suspected posttraumatic arterial injury. The appearance of dissection affecting the extracranial head and neck arteries with these techniques is well described [10–13]. Our study has shown that vertebral artery injury seen on MR angiograms after major cervical spine trauma is common. Not surprisingly, patients with complete motor and sensory deficits, indicating more severe trauma, were significantly more likely to have arterial injuries.

Prospective conventional angiography was not done in this study, as the risk of this procedure in asymptomatic patients was not thought to be clinically justified. Conventional angiography was performed in two trauma patients in whom MR angiographic findings were abnormal. Therefore, a limitation of this study is that we do not have a conventional gold standard for detecting occlusion, dissection, and/or spasm of the vertebral arteries in most of our patients. However, MR angiography is quite accurate in the detection of near or total occlusion of the extracranial head and neck vessels [11–16]; eight (73%) of the 11 abnormal vessels in this study were diagnosed as occluded. In our experience, even markedly hypoplastic vertebral arteries are readily detected and distinguished from acquired occlusions on 2D TOF MR angiograms (particularly with the benefit of interactive vascular imaging and review of the raw data). In the patient in whom there was nonvisualization of the left common carotid and left vertebral arteries on the MR angiogram (Fig. 3), conventional angiography confirmed occlusion of these vessels. Moreover, both vertebral arteries were identified in all control subjects. Regarding the three patients with focal arterial narrowing seen on MR angiograms, strong clinical proof (Fig. 2) was available in one case and angiographic proof was available in another case. Nevertheless, we cannot entirely exclude the presence of false-positive MR angiographic examinations in seven of our patients.

MR angiography is not as sensitive as conventional angiography in the detection of vertebral artery dissection [10]. The small diameter of the vertebral arteries, their variation in caliber, and their frequent tortuosity pose formidable difficulties to noninvasive imaging techniques. Therefore, we used strict criteria for diagnosing focal narrowing or increase in external diameter of a vessel on the MR angiogram. Although we used 2D TOF MR angiography in this study, this technique may not be the optimal method for detecting vertebral artery dissection. For example, the V1 (proximal) segment is poorly visualized, and evaluation of the V3 segment is hampered by flow-related artifacts [17]. For these reasons, our results may underestimate the number of patients with vertebral artery dissection.

Supplemental T1-weighted spin-echo axial images can be helpful in the detection of intraluminal and/or intramural hematoma; however, normal anatomic structures (vertebral veins, perivertebral fat) must not be confused with thrombus. Two-dimensional phase-contrast MR angiography can be done rapidly, but only one image plane can be displayed per data acquisition. Assessment of the vertebral arteries by three-dimensional (3D) TOF MR angiography with data acquisition in the coronal plane is hampered by in-plane saturation. Three-dimensional TOF MR angiography with data acquisition of the entire neck in the axial plane is very time consuming and is also prone to saturation effects [10]. Axial 3D TOF MR angiography with overlapping thin slabs reduces saturation effects but is subject to other artifacts. Regardless of the MR/MR angiography techniques that are used, it must be recognized that there is a finite amount of time available to scan critically ill trauma patients.

A low frequency of vertebrobasilar ischemia in patients with cervical spine trauma has been a general impression among our clinical staff and in published reports [8]. However, it is also apparent that vertebrobasilar ischemia in this setting can have devastating consequences; this highlights the value of a noninvasive screening test. In this series, the frequency of symptomatic vertebral artery abnormalities was low; one patient died of tonsillar herniation as a result of massive infarction of the right cerebellar hemisphere (Fig. 2). Our clinical staff was reluctant to obtain conventional angiographic correlation in seven of the nine patients whose MR angiograms were abnormal. This may be due to several factors, including confidence in the diagnostic ability of MR angiography, the presence of coexisting critical injuries, and reluctance to treat patients even if an arterial lesion was present. For example, clinicians are reluctant to fully anticoagulate patients with spinal cord injury because of a theoretical but unproved risk of precipitating or extending intramedullary hemorrhage [8].

In conclusion, our experience suggests that vertebral artery injuries due to major cervical spine trauma as determined by MR angiography are common. Patients with complete motor and sensory deficits, indicating more severe trauma, are more likely to have sustained vertebral artery lesions. Although these arterial injuries usually remain clinically occult, a small percentage of patients may suffer devastating neurologic complications of infarction in the posterior fossa. The relative risks of corelative conventional angiogra-
phy and systemic anticoagulant therapy must be weighed against the risk of developing an intracranial neurologic deficit due to a vertebral artery injury.

Although treatment options may be limited, we believe that noninvasive assessment of the vertebral arteries with MR imaging should be an integral part of the evaluation of the acutely injured cervical spine. This technique offers the possibility of detecting potentially treatable arterial injuries, before the clinical manifestations of these injuries become evident.

REFERENCES

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