Penetrating Neck Injuries: Helical CT Angiography for Initial Evaluation

PURPOSE: To report an experience with helical computed tomographic (CT) angiography as the initial procedure to rule out arterial lesions caused by penetrating neck injuries.

MATERIALS AND METHODS: During 27 months, 175 patients were referred for helical CT angiography of the neck because of clinical suspicion of arterial injuries. The protocol included a 100-mL bolus of nonionic contrast material injected at 4.5 mL/sec, with 11-second scanning delay, 3-mm collimation, and pitch of 1.3–2.0. CT images were interpreted prospectively by the emergency radiologist, and two radiologists retrospectively interpreted studies with consensus. Outcome was determined with examination of patients and their charts. The sensitivity, specificity, and positive and negative predictive values were calculated.

RESULTS: Studies in two patients were considered inadequate for diagnosis; these patients were referred for conventional arteriography and had normal findings. In 27 patients (15.6%), arterial lesions were detected. One patient had two arterial injuries. Lesions demonstrated with helical CT angiography were arterial occlusion (n = 14), pseudoaneurysm (n = 8), pseudoaneurysm and arteriovenous fistulae (n = 4), and partial thrombosis (n = 2). The remaining 146 patients had normal arteries. On the basis of these findings, patients were treated with surgery (n = 21), endovascular intervention (n = 7), and observation alone (n = 146).

CONCLUSION: Results indicate that helical CT angiography can be used as the initial method for evaluation in patients with possible arterial injuries of the neck.

Gunshot wounds cause most penetrating cervical injuries (1). Diagnostic evaluation of penetrating neck injuries in patients who do not require immediate surgical intervention is challenging because of the multiple vital structures contained within this anatomic region. Patients who have definite signs of arterial injuries or are hemodynamically unstable are taken to surgery with no further imaging procedures (1–5). For patients suspected of having arterial injuries without compromise of their vital signs, several strategies for diagnosis and management may be considered. Physical examination alone has low sensitivity for detection of vascular injuries (6). Routine surgical therapy is no longer performed in all patients with wounds that penetrate the platysma because of the high attendant morbidity (26%) and the high proportion of negative exploration results (as high as 51%) (7–9).

Conventional arteriography has traditionally been considered the method of choice for detection of arterial injuries (3,7). Use of routine arteriography has been discouraged because of the high number of normal examination results (10–12) and the availability of alternative noninvasive diagnostic methods, such as color Doppler ultrasonography (US) (13–18), magnetic resonance (MR) angiography (19–21), and helical computed tomographic (CT) angiography (22–30). Authors of several articles (22–25) on prospective series have compared helical CT angiography and conventional arteriography for detection of arterial injuries of the neck; they reported sensitivity and specificity as high as 90%–100%.

At our institution (Hospital San Vicente, Universidad de Antioquia, Medellin, Colombia), we used helical CT arteriography for 27 months as the initial diagnostic modality in patients with penetrating neck injuries. The purpose of this study was to report our
experience with helical CT angiography as the initial procedure to rule out arterial lesions caused by penetrating neck injuries.

MATERIALS AND METHODS

Patients

The study was conducted prospectively for 27 months (December 1, 1998 to March 1, 2001). At our institution, patients with cervical injuries immediately undergo surgical exploration if they are hemodynamically unstable or if they have an expanding hematoma, pulsatile bleeding, neurologic deficit, or air bubbling in the wound. Patients with diminished pulses, bruit, or thrill over the wound; nonexpanding hematoma; or nonpulsatile bleeding are candidates for helical CT angiography. This examination is also performed in patients with transcervical injuries without indication for immediate surgery and in some patients who do not have physical examination findings but have injuries close to major vasculature. The remaining patients with penetrating wounds to the neck are observed clinically. If their clinical status is stable, they are subsequently discharged.

All patients 16 years or older referred for cervical helical CT angiography after sustaining a penetrating neck injury were candidates for enrollment in this study. During the 27 months, 865 patients with penetrating neck injuries were admitted to the emergency department. Three hundred forty-four of these patients were considered to be at risk for cervical arterial injuries. Twenty-six patients had injuries close to major vasculature in zone II but no physical finding to suggest arterial involvement, and the trauma surgeons on duty at that time decided not to order any diagnostic imaging. On the basis of physical examination findings, 141 patients were taken to surgery after admission. The remaining 177 patients had an indication for helical CT angiography. Two patients who were at higher risk of nephrotoxicity induced by iodinated contrast agents because of diabetes, renal dysfunction, or both underwent conventional arteriography instead of helical CT angiography, since the volume of contrast material used for helical CT angiography is higher than that usually required for conventional angiography.

The remaining 175 patients (153 male patients, 22 female patients; mean age, 23 years; age range, 16–65 years) represented the patient population included in our study. Mechanism of injury was gunshot wounds (n = 134) or stab wounds within 72 hours after acquisition. They were blinded to the clinical status of patients and to the result of the initial interpretation. Since these radiologists were blinded to all clinical information about the patients, their interpretation of the CT angiograms was the one we used in the study for determination of diagnostic accuracy of helical CT angiography and comparison with surgical and conventional angiographic findings, as well as with clinical outcome.

Both interpretations were performed at the workstation in an interactive manner. In both cases, the radiologists were initially asked to assess helical CT angiograms for overall quality, especially for presence of artifacts resulting from patient motion or metallic bullet fragments. Image quality was classified as being adequate for interpretation or not. If it was considered not adequate, the study was not evaluated further, and those patients were referred for diagnostic conventional arteriography.

For studies considered adequate for diagnosis, the common, internal, and proximal external carotid arteries, as well as the vertebral arteries, of both sides were evaluated for abnormalities. Therefore, eight arterial segments were examined in each patient. Peripheral branches of the external carotid artery were not assessed. Abnormalities were determined as being absent (normal examination results) or present (abnormal examination results). Arterial abnormalities were classified as follows: partial thrombosis or complete obstruction (occlusion), pseudoaneurysm (extravascular collection of contrast medium), arteriovenous fistula (early filling of venous structures), and intimal flap (intraluminal linear filling defect). Finally, the radiologists were asked to look for associated, or nonarterial, abnormalities such as fractures, soft-tissue hematoma, airway injuries, and spinal cord lesions.

Follow-up

Patient outcome after admission to the hospital was used as the standard of reference for comparison with results of helical CT angiography. Patients with normal helical CT angiographic results were admitted for observation and discharged 12–24 hours later, if their clinical status remained stable. After discharge, these patients were followed-up clinically with weekly physical examinations and interviews for 4 weeks and then with monthly telephone interviews for 6 months. These examinations and telephone contacts were conducted by one of the investiga-
tors (A.S.). For patients who remained asymptomatic after clinical follow-up, we assumed that no arterial damage had been caused by the injury and that negative helical CT angiographic interpretations were true-negative results.

Patients with arterial abnormalities demonstrated at helical CT angiography were referred for conventional arteriography for endovascular therapy or were sent directly to surgery. Conventional arteriography was performed for diagnosis in subjects who were initially admitted for observation after negative helical CT arteriographic results but who later developed signs or symptoms of a potential arterial injury. Conventional arteriography was also performed for diagnosis in patients whose helical CT angiographic studies were considered not adequate for interpretation by the radiologists responsible for the initial interpretation. Findings at conventional arteriography or surgical exploration were used as the standard of reference for comparison with helical CT angiographic results in these patients. If only one side of the neck, or one artery in the affected side, was explored surgically or examined with conventional arteriography, clinical follow-up similar to that described for patients who were observed and discharged was used as the standard of reference for the remaining arteries.

**Statistical Analysis**

We calculated the sensitivity, specificity, and positive and negative predictive values, as well as the 95% CIs, for helical CT arteriography. Since an inadequate study was considered an indication to perform conventional angiography, these studies were considered false-positive interpretations for the purpose of statistical analysis.
RESULTS

Two (1.1%) of 175 helical CT angiographic studies were considered inadequate for diagnosis because of multiple artifacts arising from bullet fragments. Conventional arteriography in these patients revealed normal findings. In one patient, helical CT angiographic results demonstrated injuries in two arteries (internal carotid and vertebral arterial occlusion); all other patients had injuries in a single arterial segment. Therefore, there were injuries in 28 arterial segments in these 27 patients. Seven injuries occurred in the internal carotid artery (Fig 1), 13 in the common carotid artery (Figs 2, 3), seven in the vertebral artery, and one in the proximal external carotid artery. The Table lists the injuries and their distribution according to location and type. All of these injuries were confirmed at surgical exploration (n = 21) or conventional angiography (n = 7) performed prior to endovascular therapy.

In one patient, a small arteriovenous fistula was detected between branches of the proximal external carotid arteries and the external jugular vein at the consensus reading but not at the initial interpretation. This lesion was confirmed at conventional angiography; since the lesion required treatment with embolization, it was included in our statistical analysis. In another patient, occlusion of a branch of the external carotid artery was reported at initial interpretation but not at the retrospective consensus reading. At surgery performed for esophageal rupture, no arterial injury was found.

The remaining 146 subjects underwent conservative management and clinical follow-up for the next 6 months (mean follow-up, 46 days; range, 7 days to 6 months). Nine patients were lost to follow-up after 7 days. During clinical follow-up, none of the patients developed signs or symptoms to suggest arterial trauma.

We found lesions other than vascular injuries in 61 (34.9%) patients. These injuries were vertebral fractures (n = 21), mandibular fractures (n = 17), major airway injuries (n = 4) (Fig 4), soft-tissue hematoma compressing the airway (n = 16), and hematoma causing cord compression (n = 3) (Fig 5).

For statistical analysis, we used the retrospective consensus interpretation. The sensitivity was 100% (95% CI: 83.9%, 99.6%), the specificity was 98.6% (95% CI: 94.7%, 99.8%), the positive predictive value was 92.8% (95% CI: 75.0%, 98.8%), and the negative predictive value 100% (95% CI: 96.8%, 99.9%).

DISCUSSION

Penetrating wounds to the neck are traditionally classified in three anatomic areas—zone I, between the sternal notch and cricoid cartilage; zone II, between the cricoid cartilage and mandibular angle; and zone III, between the mandibular angle and skull base. Conventional angiography is widely accepted as the reference standard test for patients in stable condition with penetrating trauma to
zones I and III (31). Zone II injuries have usually been considered surgical, since they are relatively easier to explore. Lately, some trauma groups, including ours, have proposed a conservative approach to zone II lesions, with use of angiography only in patients who do not have clinically obvious lesions and present with wounds close to vascular structures (32,33).

Conventional angiography is a relatively safe invasive procedure with a low reported incidence of complications of 0.16%–2.0% (34), including hematomas at the puncture site, vascular spasms, thrombosis, distal embolization of atheromatous plaques and thrombus, and vascular dissection. Unfortunately, complications involving the central nervous system can be catastrophic and potentially result in permanent damage. The use of angiography in patients in stable condition with penetrating neck trauma has also been questioned because of the reported high (range, 70%–90%) number of negative examination results (10–12, 15,23,35).

Color Doppler US (13–18,36) has been proposed as a noninvasive test for the diagnosis of traumatic vascular injuries. Carotid arterial dissection, for example, is a common cause of stroke in young patients with closed trauma to the neck. It can lead to distal embolization, complete occlusion, stenosis, pseudoaneurysm development, or even vascular re-canalization. Color Doppler US gives adequate information about flow, lumen, vascular wall, and thrombus features (36). In patients with penetrating trauma to the neck, some articles (13,14) had also shown promising study results. Color Doppler US is inexpensive and completely noninvasive, and it does not require administration of contrast medium. However, it is operator dependent and may take a long time, even in skilled hands, which is not desirable in patients in potentially unstable condition. Additionally, technical difficulties diminish its usefulness in subjects with large hematomas or subcutaneous emphysema. Some areas may not be well evaluated, and complete occlusion may be missed in zones I and III (13,29,36).

MR imaging has been also described for evaluation of potential vascular injuries (19,37,38), as these lesions may arise clinically, with late manifestation and neurologic deterioration due to bleeding and embolism or ischemia. Posttraumatic dissections of the carotid artery are well depicted with this method and give exact information about extension and direct visualization of wall hematomas. Nevertheless, it has limitations for the immediate assessment of potential associated injuries mainly arising from bone structures. Furthermore, MR angiography is time consuming, and the support equipment may not be compatible with the magnet.

Helical CT has gained wide acceptance in the evaluation of a variety of traumatic and nontraumatic emergency conditions (39–43). High-quality diagnostic images are obtained in a short time; this is an essential factor to consider in critically ill patients. It also offers less discomfort for the patient and decreases costs. In the emergency setting, helical CT has gradually replaced traditional imaging techniques such as conventional radiography, conventional contrast material–enhanced studies, and conventional angiography.

Transverse images are usually sufficient to make a proper diagnosis in most patients. Reformatted and three-dimensional images are complementary in complex cases. These images are also useful in planning the surgical procedure, since the surgeons usually preferred the reconstructions that more closely resembled the conventional angiograms. In our study, the postprocessing time was no more than 15 minutes. The capability to give information about potential associated lesions from such vital structures as the cervical spine and airway (23,24,30,44) is an additional advantage that allows rapid triage of the patient. Our study findings showed associated lesions in 61 patients.

Helical CT angiography is a nonoperator-dependent diagnostic study, and results can be easily reproducible in any trauma center by using established technical parameters. Helical CT angiography has also been used to plan large facial and neck reconstructions in trauma and oncology because it allows correct assessment of the vascular anatomy and the evaluation of blunt traumatic dissection (27,28,44).

We evaluated helical CT angiography as an initial diagnostic test in patients who were hemodynamically stable and had penetrating trauma to the neck. Our results showed a high positive predictive value when correlated with surgical and angiographic findings. In cases interpreted as negative, there was no further complication during follow-up, and these patients did not require further treatment or diagnostic studies.

Helical CT angiographic limitations include artifacts caused by metal, such as dental fillings or bullet fragments that may obscure arterial segments. In these cases, helical CT angiographic results should be reported as nondiagnostic, and these patients must undergo conventional angiography. In our study, results in only two (1.1%) helical CT angiographic examinations were considered inadequate for diagnosis.

Another limitation of helical CT angiography, as compared with conventional angiography, is the inability to perform therapeutic interventions with this method. However, helical CT angiography may be used to select patients as candidates for endovascular therapy such as embolization, prosthesis placement, or temporary vascular occlusion (45–50); this occurred in seven patients in our study. Perhaps patients presenting with thrill or bruit at admission to the emergency department should not undergo helical CT angiography prior to conventional angiography because of the greater likelihood of the need for endovascular therapy, as suggested by Leblang and Nunez (29). However, not all of these patients may be suitable for this type of care, and helical CT angiography may be useful in identifying those who would benefit from surgical rather than endovascular treatment. Further studies will be needed to clarify this issue.

Subtle lesions such as intimal flaps may not be well demonstrated at helical CT angiography, as compared with conventional angiography, because of less spatial resolution. Since most patients did not have angiographic correlation, we may have underestimated the number of intimal injuries. Although some reported (51–53) results suggest that there is a benign outcome of this type of lesion with spontaneous resolution, there is also controversy around this point to be elucidated in future studies.

The percentage of positive results in our study (15.6% [27 of 173]) was slightly lower than that reported in an article (10) in which conventional angiography was used (18%–30%). This result may be because of the higher number of patients who underwent helical CT angiography, perhaps because of its noninvasive properties, time-saving benefits, the possibility of obtaining additional information, and lower cost, which made it easier to perform than any other diagnostic method, including conventional angiography. Conceivably, other types of subclinical lesions might have gone undetected during follow-up, which could also explain the slightly lower positive rate in our study. This follow-up may be insuffi-
References


