Color Doppler Sonography in Penetrating Injuries of the Neck

Berta M. Montalvo, Suzanne D. LeBlang, Diego B. Nuñez, Jr, Enrique Ginzburg, K. John Klose, José L. Becerra, and Jeffrey P. Kochan

PURPOSE: To determine whether color Doppler sonography can be a sensitive alternative to screening arteriography for identifying arterial injury in patients with penetrating traumatic neck injuries. **METHODS:** Fifty-two patients admitted to our trauma center with penetrating neck injuries (gunshot wounds and lacerations) were examined prospectively with color Doppler sonography, and findings were compared with the results of angiography (n = 44), with findings at surgery (n = 4), and with clinical status (n = 4). **RESULTS:** Color Doppler sonography correctly detected all serious injuries of the carotid arteries (n = 6; 5 diagnosed at angiography and 1 at surgery) and all injuries of the vertebral arteries (n = 4; all diagnosed at angiography). Sonography missed 1 instance of reversible narrowing of the internal and external carotid arteries and did not show 2 normal vertebral arteries. **CONCLUSION:** Color Doppler sonography was as accurate as angiography in screening clinically stable patients with zone II or III injuries and no signs of active bleeding. Our initial results suggest that in the future, sonography may be used as a screening examination for arterial lesions in patients with penetrating neck injuries.

Index terms: Neck, injuries; Neck, ultrasound; Ultrasound, Doppler

AJNR Am J Neuroradiol 17:943–951, May 1996

The diagnostic workup and management of arterial injuries in stable patients with penetrating neck trauma are subjects of controversy. Different methods have been advocated, including clinical evaluation and selective exploration (1–3) with angiography in suspected arterial injuries (4, 5), routine arteriography (6, 7), panendoscopy with arteriography (8) combined clinical and multitechnique imaging studies (9), and routine surgical neck exploration (10, 11) with angiography in selected cases (12). In stable patients, most investigators suggest an integrated clinical and radiographic workup (8, 9, 13). Results of screening angiography in these patients are negative in as many as 83% of cases (4); moreover, the procedure is costly, requires an extended hospital stay, and carries a small associated mortality rate. A reliable, noninvasive screening examination would be a welcome tool in the evaluation of arterial neck injuries and could improve cost effectiveness.

Color Doppler sonography is routinely used in screening for carotid occlusive disease. The sonographic findings of spontaneous and posttraumatic dissections have been described in several reports (14–17). Animal studies (18) have shown that in the controlled environment of the laboratory, duplex Doppler sonography is more sensitive than angiography in identifying induced arterial injuries, including occlusions, lacerations, and arteriovenous fistulas. In our trauma center we have used this imaging technique to examine a small number of patients with neck injury, and the results correlated well with angiography. We hypothesized that Doppler sonography could be a sensitive test for detecting arterial injury in penetrating traumatic neck injuries, and could be used as a substitute for screening arteriography. We then initiated a prospective study of patients with penetrating neck trauma, comparing color Doppler sonography with angiography to test this hypothesis.

Received September 29, 1995; accepted after revision January 22, 1996.

Presented in part at the annual meeting of the American Society of Neuroradiology, Nashville, Tenn, May 1994.

From the Departments of Radiology (B.M.M., S.D.LeB., D.B.N., J.L.B., J.P.K.) and Surgery (E.G.) and the Miami Project to Cure Paralysis (K.J.K.), University of Miami (Fla) School of Medicine.

Address reprint requests to Berta M. Montalvo, MD, Department of Radiology, University of Miami School of Medicine/Jackson Memorial Medical Center, 1611 NW 12th Ave, West Wing II, Room 279, Miami, FL 33136.

AJNR 17:943–951, May 1996 0195-6108/96/1705–0943

Subjects and Methods

From March 1, 1993, to January 31, 1994, a total of 128 patients were admitted to our level I trauma center with penetrating injury to the neck: 106 had arteriography of the neck and 22 patients went directly to surgery without preoperative diagnostic studies. Fifty-two of these patients were prospectively included in this study and were examined with color Doppler sonography. Inclusion criteria consisted of stable patients with penetrating cervical injuries who were admitted to the trauma center and who were candidates for angiography as part of their clinical management. Patients not examined with sonography were either not referred to the study by the trauma team or were unstable and went directly to the operating room. Penetrating injuries of the neck were classified according to their entry and exit site as being in zone I, between the suprasternal notch and the cricoid cartilage; in zone II, between the cricoid cartilage and the angle of the mandible; or in zone III, above the angle of the mandible (19).

Sonography included gray-scale imaging in transverse and longitudinal planes, color Doppler imaging in the longitudinal plane, and pulsed Doppler imaging. The carotid artery was studied from its origin to the angle of the mandible. The vertebral artery was followed from its origin to its intraforaminal course and as far superior as feasible. Spectral waveforms were obtained from the common carotid artery, the internal carotid artery, the external carotid artery, and the vertebral artery, and peak systolic velocities were recorded. The entry and exit wounds in the neck were also examined sonographically. All examinations were performed on an Acuson 128XP/10 (Mountain View, Calif) with 5-MHz and 7-MHz linear transducers. The 5-MHz transducers were optimal, since higher frequency transducers may fail to adequately depict arteries in patients with large or swollen necks.

The studies were performed in the resuscitation room or in the angiography suite, and universal 5 precautions were observed. In all patients with gunshot wounds, the stabilizing cervical collar was opened but not removed and a member of the surgical team provided neck stability. Examination of patients with open cervical collars did not pose technical problems. All studies were videotaped and reviewed prospectively by one of two radiologists; findings were recorded on a data sheet. The sonographer performing the examination and the radiologist interpreting the sonogram were blinded to the results of arteriography. The arteriograms were evaluated prospectively by one of three angiographers who was also blinded to the sonographic findings.

Sonographic findings were categorized as negative if the examinations were technically adequate, the carotid and vertebral arteries appeared normal, and the spectral waveforms were normal. Findings were considered positive if the arteries were not visible or if injuries involving the common, internal, or external carotid arteries or the vertebral arteries were detected.

Sonographic findings were compared with arteriographic results (n = 44) or with findings at neck exploration (n = 4) done for clinical indications without arteriography. Results were compared with clinical information for 4 patients who did not undergo angiography or neck exploration.

TABLE 1: Carotid arteries: comparison of sonography and angiography (n = 44)

	Angiographic Findings		No. of Cases
	Normal	Abnormal	
Sonographic Findings			
Abnormal	0	5	5
Normal	38	1	39
Total	**38**	**6**	**44**

Note.—McNemar χ^2 test showed no statistically significant difference between the two imaging methods.

Statistical comparisons were made in the 44 patients who had both sonography and arteriography. Data for carotid and vertebral artery studies were handled in separate analyses. Results of the two imaging methods (ie, angiography, the standard, and color Doppler sonography, the contender) were compared by using the McNemar test for matched pairs of dichotomous test results. Imaging findings were considered positive if for either test method an arterial injury was identified or if an artery was not depicted. If the arteries appeared normal on images obtained with that method, the result was recorded as negative (normal). The protocol was approved by the Medical Sciences Subcommittee of the Institutional Review Board.

Results

Of the 52 patients studied, 22 had lacerations (16 from stab wounds, 2 from other instruments, and 4 as a consequence of a motor vehicle accident) and 30 had gunshot wounds. There were 42 men and 10 women ranging in age from 16 to 57 years (mean age, 32 years). Entry and exit sites involved zone I in 5 patients, zone II in 35 patients, and zone III in 18 patients (6 cases involved multiple zones).

Comparison of Sonographic and Angiographic Findings

Forty-four patients had both sonography and angiography: 27 had gunshot wounds and 17 had lacerations.

Carotid arteries.—Color Doppler sonography depicted normal carotid arteries in 38 patients (17 lacerations and 21 gunshot wounds), all confirmed by angiography (Table 1). Five abnormal carotid arteries were seen with both sonography and angiography in the patients with gunshot wounds (Table 2). In 4 cases, the

TABLE 2: Abnormal carotid arteries: comparison of sonography and angiography

	Sonography	Angiography	No. of Cases
Concordant studies			
Common carotid artery	Pseudoaneurysm with intimal flap	Pseudoaneurysm with intimal flap	1
Internal carotid artery	Occlusion	Occlusion	2
	"Injury"	Dissection	1
External carotid artery branch (occipital artery)	Pseudoaneurysm	Pseudoaneurysm	1
Discordant studies			
Internal and external carotid arteries	Normal	Reversible spasm	1

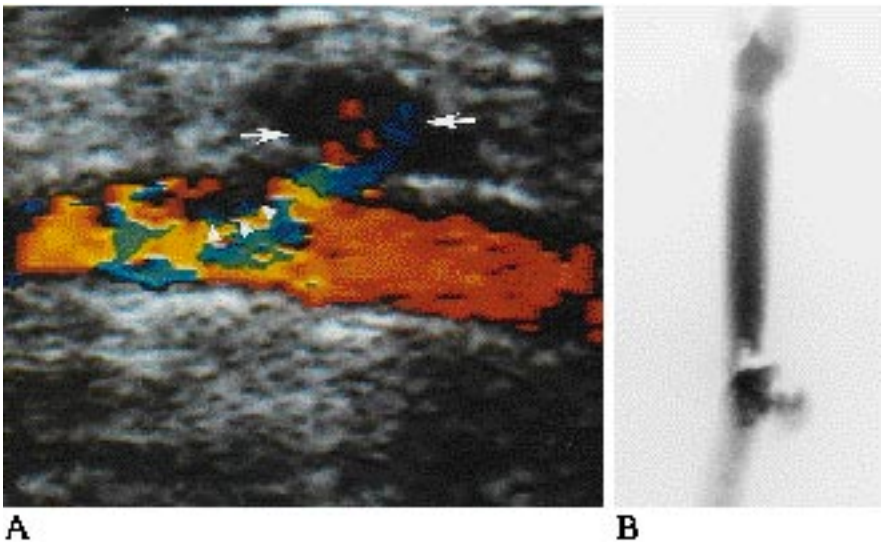

Fig 1. *A*, Longitudinal color Doppler sonogram of common carotid artery (CCA). Color flow within contained area in the soft tissues adjacent to the middle portion of the CCA is consistent with pseudoaneurysm (between *arrows*). Just distal to the pseudoaneurysm is a linear density that does not fill with color, interpreted as an intimal flap (*arrowheads*).

B, Conventional angiogram in the anteroposterior projection confirms the presence of a pseudoaneurysm of the CCA and an intimal flap.

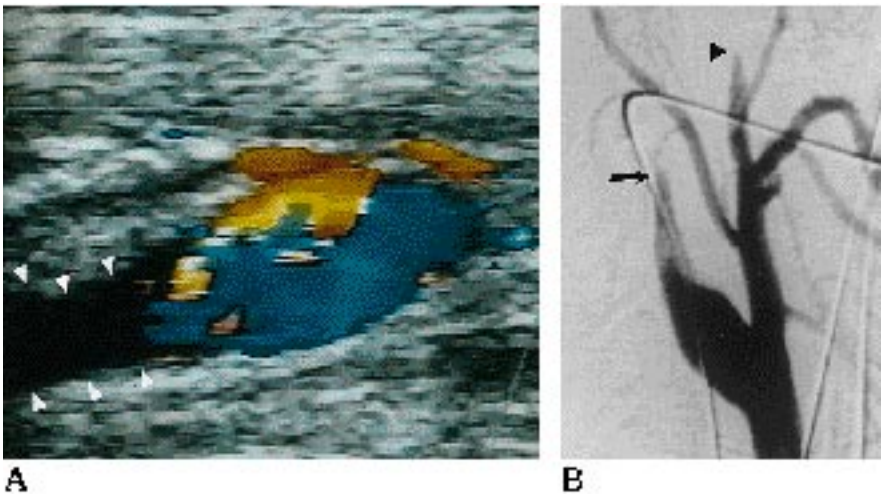

Fig 2. *A*, Longitudinal color Doppler sonogram of the carotid bulb. Marked reversal of flow within the bulb and lack of color of the proximal internal carotid artery (ICA) are consistent with occlusion (*arrowheads*).

B, Angiogram in the lateral projection confirms narrowing leading to total occlusion of both the ICA (*arrow*) and the external carotid artery (*arrowhead*).

specific diagnosis was made at sonography: pseudoaneurysm of the common carotid artery (n = 1) (Fig 1), occlusion of the internal carotid artery (n = 2) (Figs 2 and 3), and pseudoaneurysm of a distal branch of the external carotid artery (n = 1). In 1, sonography detected a significant injury at the carotid bifurcation, but a specific diagnosis was not possible. Angiography showed a dissection of the internal carotid artery. No statistically significant difference between angiography and sonography was found using the McNemar test.

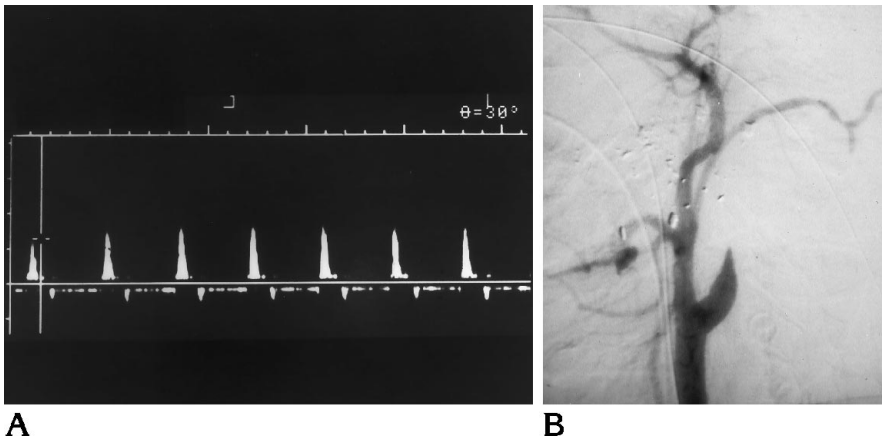

Fig 3. *A*, Pulsed Doppler sonogram of internal carotid artery (ICA) shows absence of diastolic flow with thump artifact indicative of occlusion.

B, Angiogram in the lateral projection confirms narrowing leading to total occlusion of the ICA.

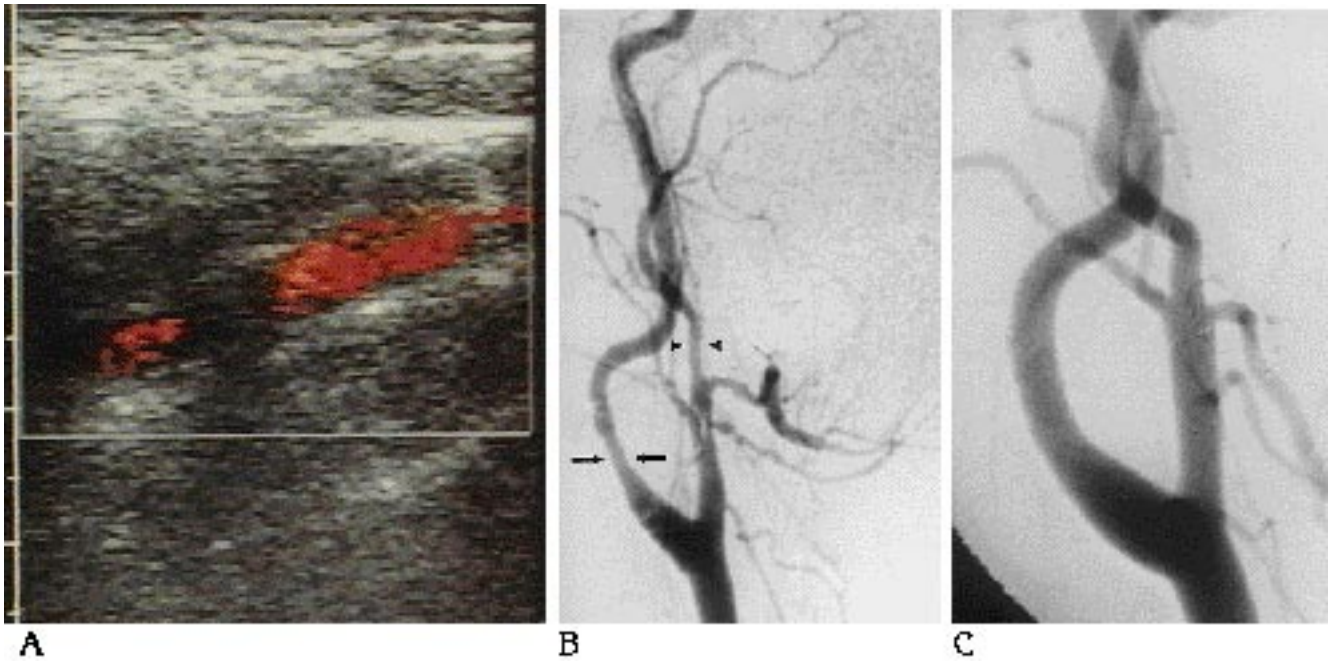

Fig 4. *A*, Longitudinal color Doppler sonogram of the internal carotid artery (ICA). Shadowing from air in the soft tissues obscures view of proximal part of ICA. Findings were initially interpreted as normal, but a retrospective analysis suggested narrowing of the distal portion of the ICA.

B, Angiogram shows nonocclusive narrowing of the ICA (*arrows*) and branches of the external carotid artery (*arrowheads*), consistent with spasm.

C, Follow-up angiogram obtained on second day of hospitalization shows complete resolution of the spasm.

The internal carotid occlusions were not treated definitively, since the patients were asymptomatic and the arteriograms showed adequate collateralization in both the anterior and the posterior circulation. One of the patients suffered a major stroke 2 days after trauma and subsequently died. The pseudoaneurysm of the common carotid artery was resected and treated with an interposition graft. The dissection of the internal carotid artery was treated conservatively. The pseudoaneurysm of the occipital branch was embolized endovascularly.

One patient with a gunshot wound who had normal sonographic findings had mild narrowing of both internal and external carotid arteries at angiography, probably caused by spasm (Fig 4). On retrospective review of the color images, air in the soft tissues obscured the internal carotid artery and the external carotid artery was narrowed. The patient was treated conserva-

tively. At follow-up arteriography, both arteries were judged normal.

Vertebral arteries.—Of 39 patients with normal vertebral arteries at angiography, sonographic findings agreed with angiographic results in 37. In 2 patients, the vertebral artery at the site of injury was not depicted by sonography but was normal at angiography (Table 3). One of these patients had a small vertebral artery with a dominant contralateral artery. The other patient had a thick muscular neck and significant swelling.

In one patient, sonography showed a normal vertebral artery that was not seen at arteriography. A second retrospective review of the arteriogram showed an anomalous origin of the vertebral artery from the aortic arch.

Four vertebral artery injuries (three caused by gunshot wounds, one by a stab wound) were diagnosed at angiography; all were occlusions and they were detected prospectively with sonography. In two patients, the spectral waveform was consistent with occlusion (Fig 5) and in another two patients sonography did not show the vertebral artery (see Table 4). None of these patients was treated. Statistical comparison of the diagnostic results of the two imaging methods by means of the McNemar test did not show a significant difference.

TABLE 3: Vertebral arteries: comparison of sonography and angiography (n = 44)

	Angiographic Findings		No. of Cases
	Normal	Abnormal	
Sonographic Findings			
Abnormal	2	4	6
Normal	37	1	38
Total	**39**	**5**	**44**

Note.—McNemar χ^2 test showed no statistically significant difference between the two imaging methods.

Comparison of Sonographic Findings and Results of Neck Exploration

Four patients who had sonography went directly to surgery. In one patient with a gunshot wound, gray-scale sonography showed a large diameter in the middle portion of the common carotid artery, an irregular posterior wall, and air in the carotid sheath (Fig 6). Soon after sonography was started, the patient began to bleed actively from the neck; the examination was terminated and the patient went directly to surgery without preoperative angiography. At surgery, a laceration of the posterior wall of the common carotid artery was found and an interposition graft was placed. The three other patients had lacerations, and results of sonography of the cervical carotid and vertebral arteries

TABLE 4: Abnormal vertebral arteries: comparison of sonography and angiography

	Sonography	Angiography	No. of Cases
Concordant studies			
	Occlusion	Occlusion	2
	Not visible	Not visible	1
	Not visible	Occlusion	1
Discordant studies			
	Not visible	Normal	1
	Normal	Not visible	1

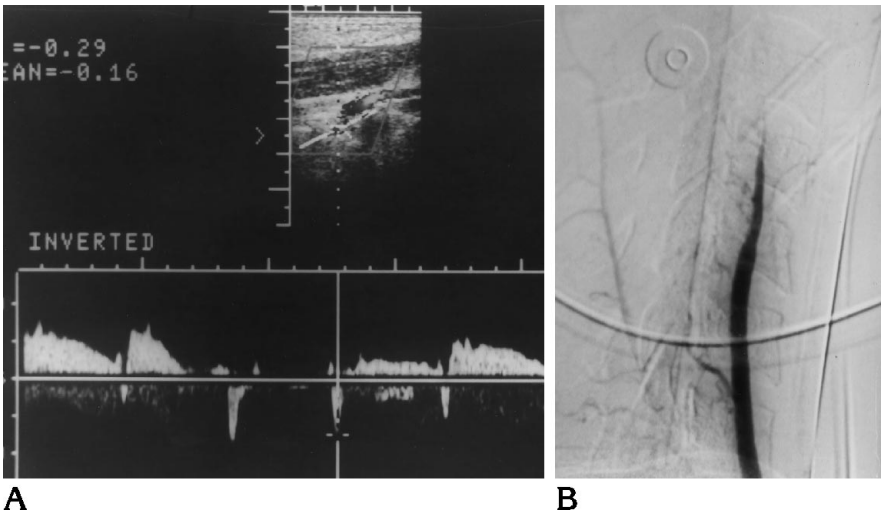

Fig 5. *A*, Pulsed Doppler sonogram of vertebral artery shows abnormal spectral pattern with cephalic and caudal flow, suggestive of a distal occlusion.

B, Angiogram in the lateral projection shows total occlusion of the vertebral artery.

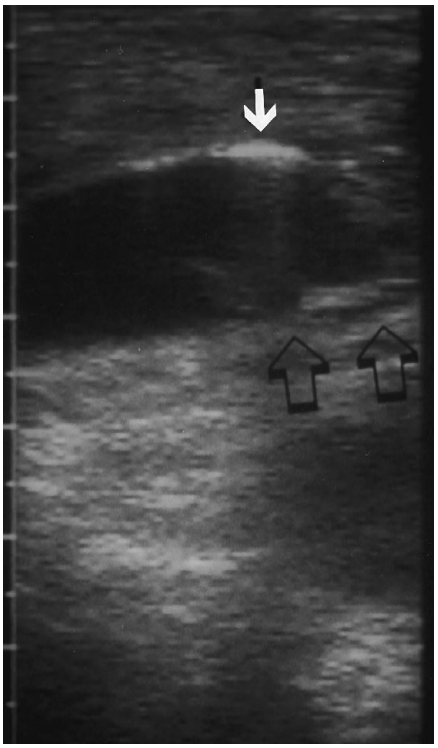

Fig 6. Longitudinal gray-scale sonogram of the common carotid artery (CCA). The caliber of the CCA is larger in the more cephalad portion of the vessel and there is an irregularity of the posterior wall (*open arrows*). At surgical exploration there was a posterior wall laceration requiring an interposition graft. Also note the hyperechoic foci with posterior shadowing along the anterior wall of the CCA (*solid arrow*), denoting air within the carotid sheath.

were normal. At surgery for active bleeding, the cervical arteries were normal in all three patients: one patient had a transection of the external jugular vein and a laceration of the anterior jugular vein, one was bleeding from small muscular arterial branches, and one had normal findings at surgical exploration.

Clinical Information

Four patients who had sonography did not undergo angiography or surgery. In one patient sonography detected occlusion of the right internal carotid artery and the right vertebral artery. Clinically, the patient was deemed to have suffered a devastating wound with severe anoxic insult and no functional prognosis. The patient died 2 days after admission. Sonograms in the other three patients showed normal findings. One patient with a superficial stab wound to the chin underwent repair for a submental laceration, but clinical presentation did not warrant further investigation for vascular injury. One patient had complex facial lacerations and mandibular fractures resulting from a motor vehicle accident (these injuries were repaired), and a hypopharyngeal injury, which was discovered at surgery; however, the neck vessels were not explored. In a patient with a superficial BB shot to the neck, sonography convincingly located the BB and showed its relationship to the neck vessels (Fig 7). A chest radiograph supported the sonographic findings; the patient refused to undergo angiography.

Other Sonographic Findings and Time Considerations

Sonography identified the presence of extraluminal hematomas in 11 patients (Fig 8) and air in the soft tissues in 9 (Figs 4 and 6). The presence of air in the soft tissues occasionally made visualization of the cervical arteries more difficult, however, it interfered with the ability to obtain a diagnostic study in only 1 case of spasm of the internal and external carotid arteries (Fig 4).

Color Doppler sonography was most useful in detecting normal or injured arteries. Gray-scale imaging did not contribute any additional information, except in the case of the laceration to the common carotid artery in which color Doppler imaging was not performed owing to the patient's changing clinical status that necessitated termination of the examination. Pulsed Doppler imaging helped confirm occlusions. The examinations required 15 to 30 minutes to complete.

Discussion

Because serious injuries resulting from neck trauma may be clinically asymptomatic in 20% to 33% of patients (6, 7, 13, 20), and because 56% of routine neck explorations may produce negative findings (3), most researchers suggest an integrated clinical and noninvasive approach to these injuries that includes angiography (8, 13). In stable patients, routine angiography is performed with subsequent neck exploration in those in whom a vascular injury is identified. Screening angiography in penetrating neck lesions is very sensitive, but findings are negative in up to 92% of stab wounds and in 73% of gunshot wounds (4).

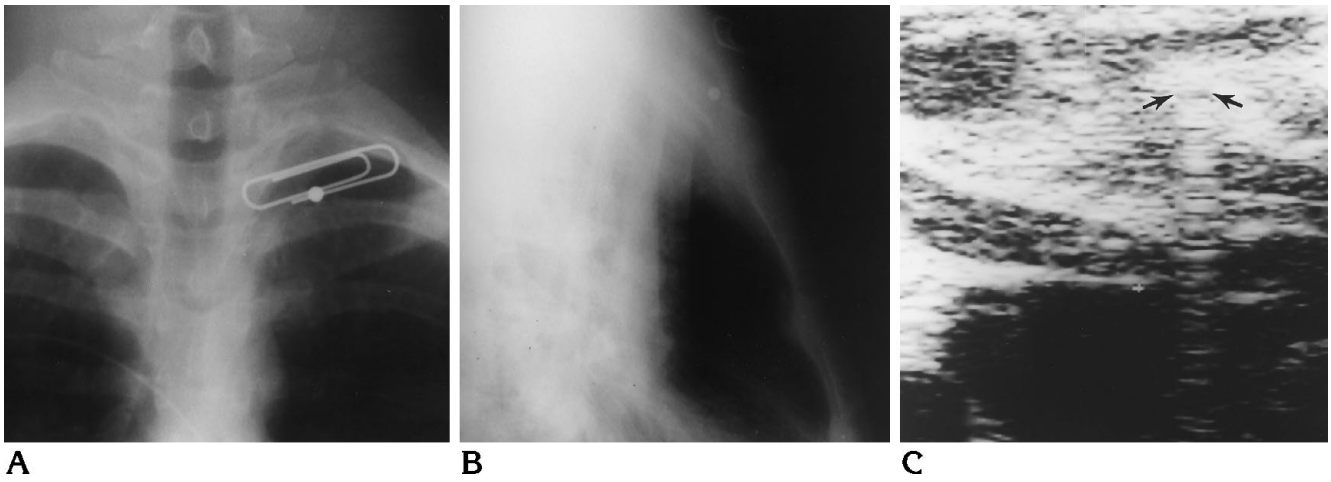

Fig 7. Posteroanterior (*A*) and lateral (*B*) chest radiographs show a BB in the soft tissues of the anterior part of the neck.
C, Transverse gray-scale sonogram at the level of the proximal portion of the common carotid artery (CCA). Hyperechoic interface (*arrows*) with reverberation artifact representing the pellet is clearly seen in the soft tissues anterior to the intact and patent CCA. The patient refused angiography.

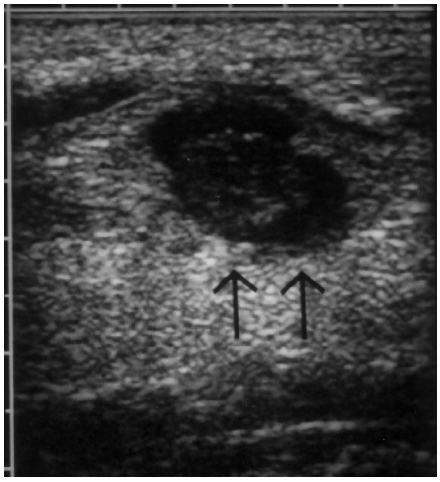

Fig 8. Longitudinal sonogram of zone II of the neck shows a hypoechoic mass in the soft tissues (*arrows*) without flow and anterior to vascular structures, consistent with hematoma.

At our level I trauma center, approximately 140 patients with penetrating neck injuries are seen each year. Patients who are unstable or who have clinical signs suggesting significant vascular injury (profuse active bleeding, signs of cerebral ischemia, expanding hematoma) are operated on immediately. All other patients usually have arteriography and esophagography, regardless of the clinical findings. Our hypothesis was that color Doppler sonography could replace routine angiography as a screening test, and that only patients with abnormal sonographic findings or technically suboptimal examinations would require arteriography.

In the assessment of the carotid artery, sonographic results agreed with findings at angiography and surgery, correctly identifying all serious injuries (Tables 1 and 2), including those requiring arterial reconstruction (Figs 1 and 7) or embolization of a pseudoaneurysm. Statistical comparisons between the two imaging methods showed no significant differences. Two carotid occlusions were identified, neither of which required further therapy. We recommend that all patients with positive findings at sonography undergo angiography so that a management plan can be determined.

One case of reversible spasm of the internal and external carotid arteries was not initially detected with sonography, partly because of an error in interpretation and partly because of an inability to recognize that the presence of air interfered with complete visualization of the arteries. This patient did not require therapy. Although air in the soft tissues was present in nine patients, it only interfered with correct interpretation in one (Fig 4). Nevertheless, it is essential to be able to recognize the presence of air and to evaluate whether it limits visualization of the arteries. Any technically limited study should be assumed to be incomplete, and the patient should undergo angiography.

Sonography can locate the vertebral artery at its origin and follow it in its foraminal course with a high rate of vessel depiction (21), although clarity is not as good as it is for the carotid circulation. We were able to visualize the

vertebral arteries completely in most patients in this study. Sonography correctly indicated all significant vertebral injuries (Tables 3 and 4, Fig 5); however, it did not show two normal arteries. There were no significant differences in the statistical comparison between the two imaging methods.

Management of vertebral injuries varies among institutions. Embolization of vertebral arteries has been advocated in order to avoid embolization of clot from injured intima to the posterior circulation (Becerra JL, Kochan J, Nuñez D Jr, DePrima SD, Coin CG, LeBlang SD, "Neurointerventional Therapy of the Vertebral Artery after Traumatic Occlusion," presented at the annual meeting of the American Society of Emergency Radiology, San Diego, Calif, March 1993). In institutions that follow this practice, any sonographic study that fails to show the vertebral artery should be followed by arteriography.

A limitation of our study is that in zone I injuries the subclavian arteries were not routinely included in the sonographic examination. In addition, some zone I injuries may not have been included in the study population, because the major clinical indication was subclavian/axillary injury and not carotid injury. Another limitation is the absence of any arteriovenous fistulas in this series.

On the basis of our results, we propose the following imaging protocol. Clinically stable patients with zone II or III injuries and no signs of active bleeding, and in whom sonographic findings are complete and normal, may not need any further imaging studies or neck exploration, especially in the case of stab wounds or lacerations. Patients with incomplete or technically suboptimal sonograms may benefit from angiography. In patients with gunshot wounds, further information may be obtained from computed tomography of the neck (LeBlang SD, Nuñez DB, Post MJD, Serafini A, Montalvo BM, Becerra JL, "CT of the Neck in Penetrating Trauma: Predictive Value for Vascular Injuries," presented at the annual meeting of the Radiological Society of North America, Chicago, Ill, November 1994). Patients who have a serious injury detected with sonography, and who are candidates for surgery or intervention, warrant angiography so that the procedure can be planned and the branch vessels can be examined.

Sonography proved to be fast and sensitive in our study population. Potential cost savings are significant considering the difference in cost between sonography and arteriography and the added cost of extended hospital stays in patients who undergo angiography. In our study group, sonography was virtually equivalent to angiography: in no instance in which sonography showed normal arteries was a serious injury depicted at angiography. However, the findings of this investigation should not be considered definitive, since the number of patients and the number of positive findings were small, and this was a first-time effort at equating the two techniques in a diagnostic situation. Caution should be used in attempting to rely on sonography until further information is available that corroborates or refutes the present findings. We encourage replication studies at other institutions in order to support our conclusions. If our results are corroborated, substitution of sonography for angiography for screening purposes could ultimately result in both time and cost savings without altering patients' treatment.

Acknowledgments

We thank Marilyn Lewis for her professional, patient, and willing assistance in the preparation of this manuscript, and Monique Riemann for the excellence with which she performed carotid sonography under trying circumstances at all hours of the day and night.

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