World J. Surg. 21, 41–48, 1997

WORLD
Journal of
SURGERY

Evaluation of Penetrating Injuries of the Neck: Prospective Study of 223 Patients

D. Demetriades, M.D., Ph.D.,[1] D. Theodorou, M.D.,[1] E. Cornwell, M.D.,[1] T.V. Berne, M.D.,[1] J. Asensio, M.D.,[1] H. Belzberg, M.D.,[1] G. Velmahos, M.D.,[1] F. Weaver, M.D.,[2] A. Yellin, M.D.[2]

[1]Division of Trauma and Critical Care, School of Medicine, University of Southern California, 1510 San Pablo Street, Los Angeles, California 90033, U.S.A.
[2]Division of Vascular Surgery, Department of Surgery, HCC, School of Medicine, University of Southern California, 1510 San Pablo Street, Los Angeles, California 90033, U.S.A.

Abstract. The objective of this study was to assess the role of clinical examination, angiography, color flow Doppler imaging, and other diagnostic tests in identifying injuries to the vascular or aerodigestive structures in patients with penetrating injuries to the neck. A prospective study was made of patients with penetrating neck injuries. All patients had a careful physical examination according to a written protocol. Stable patients underwent routine four-vessel angiography and color flow Doppler imaging. Esophagography and endoscopy were performed for proximity injuries. The sensitivity, specificity, and predictive values of physical examination, color flow Doppler studies, and other diagnostic tests were assessed during the evaluation of vascular and aerodigestive tract structures in the neck. Altogether 223 patients were entered in the study. After physical examination 176 patients underwent angiography and 99 of them underwent color flow Doppler imaging. Angiographic abnormalities were seen in 34 patients for an incidence of 19.3%, but only 14 (8.0%) required treatment. Color flow Doppler imaging was performed on 99 patients with a sensitivity of 91.7%, specificity 100%, positive predictive value (PPV) 100%, and negative predictive value (NPV) 99%. These values were all 100% when only injuries requiring treatment were considered. None of the 160 patients without clinical signs of vascular injury had serious vascular trauma requiring treatment (NPV 100%), although angiography in 127 showed 11 vascular lesions not requiring treatment. "Hard" signs on clinical examination (large expanding hematomas, severe active bleeding, shock not responding to fluids, diminished radial pulse, bruit) reliably predicted major vascular trauma requiring treatment. Among 34 of the 223 total patients (15.2%) admitted with "soft" signs, 8 had angiographically detected injuries, but only one required treatment. An esophagogram was performed on 98 patients because of proximity injuries (49 patients) or suspicious clinical signs (49 patients), and two of them showed esophageal perforations. None of the 167 patients without clinical signs of esophageal trauma had an esophageal injury requiring treatment. It was concluded that physical examination is reliable for identifying those patients with penetrating injuries of the neck who require vascular or esophageal diagnostic studies. Color flow Doppler imaging is a dependable alternative to angiography. An algorithm for the initial assessment of neck injuries is suggested.

Penetrating injuries of the neck are generally considered difficult to assess and manage. The neck has a dense concentration of vital structures, and surgical exposure is often difficult. Most trauma centers advocate extensive workup by means of angiography, contrast studies, and endoscopy. In the present study we investigated the role of these diagnostic modalities and compared their accuracy with that of a careful clinical examination.

Correspondence to: D. Demetriades, M.D., Ph.D., Department of Surgery, HCC, University of Southern California, 1510 San Pablo Street, Los Angeles, CA 90033, U.S.A.

Patients and Methods

A prospective study was performed at the Los Angeles County and University of Southern California (LAC/USC) Medical Center during a 20-month period (July 1993 to March 1995). The LAC/USC Medical Center is an American College of Surgeons (ACS)-certified level I trauma center with about 6500 trauma admissions per year. The study was approved by the medical center's Institutional Review Board. All patients with penetrating injuries of the neck were eligible for inclusion. Exclusion criteria were obvious superficial wounds or death before admission. All patients were assessed clinically according to a protocol by a senior surgical resident (PG 4 or 5) and an attending trauma surgeon, who were in the hospital on a 24-hour basis. The clinical examination focused on signs and symptoms suggestive of injuries to major vessels, aerodigestive tract, spinal cord, and nerves (Fig. 1).

The site of injury was described by neck triangles and zones. Zone I was defined as the area between the clavicle and the cricoid cartilage, zone II the area between the cricoid and the inferior border of the mandible, and zone III the area between the inferior border of the mandible and the base of the skull. The direction of the wound was described as: toward the midline, toward the clavicle, away from the midline or clavicle, or cannot assess. After the clinical examination, a chest radiograph was obtained in stable patients.

Patients with one or more of the following signs or symptoms underwent emergency surgery with no other investigations: severe active bleeding, shock not responding to fluid resuscitation, air bubbling through the wound, and dyspnea. All other patients underwent four-vessel angiography and subsequently a color flow Doppler (CFD) study. This order was chosen because of the limited availability of CFD at night and on weekends. The CFD was performed by a vascular technician who was blinded to the

A. Site of Injury:

☐ Anterior neck triangle (anterior to SMS muscle)
☐ Posterior neck triangle (posterior to SMS muscle)
☐ Zone I (between clavicles and cricoid)
☐ Zone II (between cricoid and angle of mandible of skull)
☐ Zone III (between angle of mandible and base of skull)

Wound Tract:

☐ Towards midline
☐ Towards clavicle
☐ Away from midline or
☐ Can't assess

B. Vascular Structures:

1. Active bleeding: ☐ None, ☐ Minor, ☐ Moderate, ☐ Severre
2. Hypovolemia: ☐ BP > 100, ☐ BP 60-90, ☐ BP < 60
3. Hematoma: ☐ None, ☐ Small, ☐ Moderate, ☐ Large, ☐ Expanding, ☐ Pulsatile
4. Peripheral pulses (compare with contralateral):
   Distal carotid: ☐ Normal, ☐ Diminished, ☐ Absent
   Superficial temporal: ☐ Normal, ☐ Diminished, ☐ Absent
   Brachial or radial: ☐ Normal, ☐ Diminished, ☐ Absent
5. Bruit: ☐ No, ☐ Yes (if so, where_____)

C. Larynx/Trachea, Esophagus:

1. Hemoptysis (ask patient to cough): ☐ Yes, ☐ No
2. Air bubbling through wound? ☐ Yes, ☐ No (ask patient to cough)
3. Subcutaneous emphysema: ☐ Yes, ☐ No
4. Hoarseness: ☐ Yes, ☐ No
5. Pain on swallowing sputum: ☐ Yes, ☐ No
6. Hematemesis: ☐ Yes, ☐ No

D. Nervous System:

1. GCS: ☐ Eye response, ☐ Verbal response, ☐ Motor response
   Total GCS_____
2. Localizing signs:
   Pupils:
   Limbs:
   Cranial nerves:
   Facial n.: ☐ Normal, ☐ Abnormal
   Glossophalyngeal n. (check midline portion of soft palate): ☐ Normal, ☐ Abnormal
   Recurrent laryngeal n. (horseness, effective cough): ☐ Normal, ☐ Abnormal
   Accessory n. (lift the shoulder): ☐ Normal, ☐ Abnormal
   Hypoglossal n. (check midline position of tongue): ☐ Normal, ☐ Abnormal
   Spinal cord: ☐ Normal, ☐ Abnormal (specify)
   Horners syndrome (myosis, ptosis): ☐ Yes, ☐ No
   Brachial plexus: median n. (fist): ☐ Normal, ☐ Abnormal
   radial n. (wrist extension): ☐ Normal, ☐ Abnormal
   ulnar n. (abduction/adduction of fingers): ☐ Normal, ☐ Abnormal
   musculocutaneous n. (flexion of forearm): ☐ Normal, ☐ Abnormal
   axillary n. (abduction of arm): ☐ Normal, ☐ Abnormal

Fig. 1. Clinical examination.

angiographic findings. Esophagoscopy, laryngoscopy, and contrast swallow studies were liberally performed on patients with proximity injuries, pain on swallowing, hemoptysis, and hoarseness. The sensitivity, specificity, predictive values, and percentage of correct classification for physical examination, CFD, and other investigations were assessed when evaluating the major neck vessels and aerodigestive system. Each indicator was estimated by a 95% confidence interval, which was derived using a relation between the F distribution and the binomial distribution.

Results

Patients

During a 20-month period 223 patients with penetrating injuries of the neck were admitted to the LAC/USC Medical Center. Most victims were male (89%), and the mean age was 28.8 years (range 2–82 years). Altogether 97 patients (43%) sustained a gunshot wound (GSW), 89 (40%) a knife wound, 10 (4%) a shotgun injury, and 27 (12%) another penetrating injury. Zone II was the most commonly involved area (105 patients, 47%), followed by zone I (40 patients, 18%), and zone III (43 patients, 19%). There was involvement of more than one zone in 35 patients (16%).

Vascular Assessment

The clinical findings of the vascular examination are shown in Table 1. Most patients (160, or 71.7%) had no signs suggestive of vascular trauma. The most common abnormal finding was a large or moderate-size hematoma (13.1%), followed by shock (10.0%), significant external bleeding (5.8%), and a diminished radial pulse (1.8%). GSWs were significantly more likely to result in a large or moderate-size hematoma than knife injuries [20.6% versus 6.7%; $p = 0.01$; odds radio 3.6; 95% confidence intervals (CI), 1.3 and 10.7). Active bleeding was present with equal frequency in both mechanisms of injury. Knife injuries were more likely to be asymptomatic than GSWs (Table 1).

All 223 patients underwent a clinical examination according to a written protocol. Forty-seven patients did not undergo angiographic evaluation because of life-threatening problems that required an emergency operation (19 patients) or because they refused angiography (28 patients). The remaining 176 patients underwent four-vessel angiography. Abnormal angiographic findings were identified in 34 of these 176 patients (19.3%), but only 14 of the patients (8.0%) required treatment of the vascular lesions. The remaining 20 patients, who had nine vertebral artery (VA) occlusions, one VA intimal tear, one high internal carotid artery (ICA) occlusion, two small common carotid artery (CCA) aneurysms, two minor CCA intimal tears, and eight thrombosed small named vessels were successfully managed nonoperatively. The most common vascular injury was a VA lesion, which was found in 7.4% (13 cases) of the 176 patients evaluated angiographically. A subclavian artery injury was found in four patients (2.3%). The overall incidence of vascular injuries diagnosed at operation or angiography was 20.2% (45 of 223 patients), but only 11.2% (25 patients) required surgery or embolization.

Ninety-nine patients were assessed by both angiography and CFD. The remaining patients were not assessed by CFD because of limited after-hours availability of the vascular technician or because an emergency operation was necessary. With angiography as the gold standard, CFD accurately identified 11 vascular injuries (6 VA, 4 CA, 1 subclavian artery) and was falsely normal in one patient with small intimal tears of both the CCA and VA. This patient was successfully managed without surgery. Repeat angiography 1 month after the injury showed a normal VA and a stable carotid lesion. Overall, the sensitivity of the CFD was 91.7%, the specificity 100%, the positive predictive value (PPV) 100%, and the negative predictive value (NPV) 99%. The overall correct classification was 99%. If only vascular injuries requiring treatment were included, all values were 100%. The confidence interval for sensitivity and PPV had limits from 29% to 100% due to the small number of cases requiring treatment (3% in the sample of 99 patients).

Altogether 160 patients (71.7%) had no clinical signs suggestive of vascular injury, and none of them required operation or any other form of treatment (specificity and NPV were both 100%). Angiography was performed on 127 patients, and another 5 patients were operated on because of other associated injuries requiring surgery. None of the five patients who underwent neck exploration had vascular injuries. Angiography revealed 11 vascular injuries (8.3%), none of which required any type of treatment (Table 2). CFD was performed on 81 asymptomatic patients and accurately identified all six vascular injuries diagnosed by angiography (Table 2). With angiography or surgical exploration used as

Table 1. Clinical assessment of vascular structures on admission (223 patients).

Clinical findings	Overall (no.)	GSWs (no.)	Knife wounds (no.)	GSWs vs. knife wounds *p*
Severe/moderate bleeding	13/223 (5.8%)	4/97 (4.1%)	6/89 (6.7%)	0.52
Large/moderate hematoma	29/223 (13.0%)	20/97 (20.6%)	6/89 (6.7%)	0.01*
Shock (BP, systolic ≤90 mmHg)	22/223 (9.9%)	13/97 (13.4%)	7/89 (7.9%)	0.33
Diminished peripheral pulse	11/223 (4.9%)	8/97 (8.2%)	3/89 (3.4%)	0.30
No sign of vascular injury	160/223 (71.7%)	63/97 (64.9%)	72/89 (80.9%)	0.02*

GSWs: gunshot wounds; BP: blood pressure.
*Statistically significant difference between GSWs and knife wounds.

Table 2. Abnormal angiography in patients with normal clinical examination.

Patient no.	Zone	Angiography	Color flow Doppler	Comments
33	I, II	Small false aneurysm CCA	Small false aneurysm CCA	Nonoperative management
44	II	Small false aneurysm CCA	Small false aneurysm CCA	Nonoperative management
74	III	Minor extravasation from VA	Not performed	Nonoperative management
104	II	Occluded facial artery	Not performed	Nonoperative management
136	II	VA occlusion	VA occlusion	Nonoperative management
140	I, II	Minor extravasation from thyroid artery	Not done	Nonoperative management
145	III	VA occlusion	Not done	Nonoperative management
155	I, II	VA occlusion	VA occlusion	Quadriplegia, nonoperative management
190	II	VA occlusion	VA occlusion	Quadriplegia, nonoperative management
198	III	Minor stenosis ICA	Minor stenosis ICA	Nonoperative management
201	I, II, III	Occlusion facial artery	Not done	Nonoperative management

CCA: common carotid artery; ICA: internal carotid artery; VA: vertebral artery.

the gold standard, the absence of clinical signs suggestive of vascular injuries (no active bleeding, no significant hematoma, no bruit, normal radial pulses) had an NPV of 91.7% (95% CI 86–96%). However, when only injuries requiring treatment were taken into account, the NPV of the clinical examination was 100% (95% CI 97–100%). When clinical examination was combined with CFD, the NPV for both angiographic abnormalities or the need for therapy was 100%.

There were 63 patients who had one or more signs of vascular trauma. Twenty-nine of these symptomatic patients had "hard" signs (large expanding hematomas, severe active bleeding, unexplained shock not responding to fluids, diminished radial pulse, bruit), and 28 had other injuries (26 vascular, 2 aerodigestive), giving a PPV of 96.6%, although only 26 required surgery or angiographic embolization. Thirty-four patients had soft signs of vascular injuries, and vascular injuries were found in eight, one of which required treatment. Only 15 of 22 (68.2%) patients with shock on admission had arterial injuries proved angiographically or operatively.

Color flow Doppler studies were performed on 18 patients with signs suggestive of vascular injuries; and with angiography as the gold standard there were true positives in five cases and a false negative in one case. The injury missed by CFD was an intimal tear to the CCA and VA that did not require operation.

Aerodigestive Assessment

Signs or symptoms suggestive of aerodigestive injuries, such as painful swallowing, hoarseness, subcutaneous emphysema, dyspnea, and air leaking through the wound, were found in 64 (29.6%) of 216 patients in whom a clinical examination was performed (in nine patients it was not possible because of endotracheal intubation or severe head injury). Ten patients (4.5%) required surgical repair (six pharynx, two trachea, three esophagus, three larynx). None of the 152 asymptomatic patients had a significant injury requiring operation (NPV 100%). Table 3 shows the incidence and signs and symptoms for both GSWs and knife wounds.

A contrast swallow study was performed on 98 patients because of proximity injuries (49 patients) or suspicious clinical signs (49 patients). An esophageal injury was diagnosed in two patients (2.0%). Both patients had clinical signs suggestive of aerodigestive tract trauma. Esophagoscopy was performed on 22 patients and was normal in all. Laryngoscopic evaluation was performed on 149 patients with proximity injuries or suspicious clinical signs, and abnormal findings were recorded in 25 of them (16.8%) (7 vocal cord dyskinesia and 22 laryngeal or pharyngeal edema or blood). GSWs were more likely to be associated with abnormal endoscopic findings than were knife injuries (24.6% versus 8.5%: $p = 0.02$, 95% CI 1.1 and 11.8). Only five patients with abnormal laryngoscopy required an operation, and the others were successfully managed nonoperatively.

Chest radiograms were obtained from 217 patients (97.3%), and an abnormality was diagnosed in 43 of them (19.8%). The most common abnormal finding was a hemopneumothorax (40 cases), followed by an elevated diaphragm (2 cases), and a widened mediastinum (1 case).

Management

Overall, 83 patients (37.2%) had 137 significant injuries (Table 4), but only 38 (17.0%) required an operation or angiographic

Table 3. Clinical assessment of the aerodigestive tract (216 patients).

Clinical finding	Overall (no.)	GSWs (no.)	Knife wounds (no.)	GSWs vs. knife wounds p
Pain on swallowing	34/216 (15.7%)	15/95 (15.8%)	12/84 (14.3%)	0.86
Hoarseness	18/216 (8.3%)	10/95 (10.5%)	7/84 (8.3%)	0.75
Subcutaneous emphysema	15/216 (6.9%)	9/95 (9.5%)	5/84 (5.9%)	0.50
Air leak through wound	6/216 (2.8%)	4/95 (4.2%)	2/84 (2.4%)	0.65
No signs of aerodigestive injury	152/216 (70.4%)	61/95 (64.2%)	65/84 (77.4%)	0.07

Table 4. Injured structures in 83 patients.

Structure	No.
Vascular	
Carotid arteries	13 (CCA = 5, ICA = 4, ECA = 4)
Subclavian artery	4
Vertebral artery	15
Internal jugular vein	3
External jugular vein	3
Subclavian vein	1
Small named vessels	9
Visceral	
Pharynx	6
Larynx	3
Trachea	2
Esophagus	3
Hemopneumothorax	40
Nervous system	
Spinal cord	15
Nerve injury	20
Total injured structures	137

CCA: common carotid artery; ICA: internal carotid artery; ECA: external carotid artery.

embolization. The incidence and type of injury sustained are shown in Table 5. GSWs were more likely to cause vascular, aerodigestive tract, spinal cord, and nerve injuries than knife injuries (Table 5). The incidence of vascular and aerodigestive tract injuries according to zones is shown in Table 6.

A total of 38 patients (17.0%) were subjected to an emergency operation, but in only 30 of them (13.5%) was the operation therapeutic (16.5% for GSWs versus 10.1% for knife wounds; $p = 0.29$). Overall, six patients had a negative operation (2.7% of the total), and another two patients had a nontherapeutic operation (both patients had a thrombosed vertebral artery that did not require treatment). Active bleeding from a vertebral artery in one patient was successfully embolized. Another patient with a high vertebral artery false aneurysm and arteriovenous fistula had proximal angiographic embolization and distal surgical ligation. In one patient subjected to an emergency operation because of an obvious tracheal injury, an esophageal perforation was missed. The lesion was diagnosed 2 days later and was successfully repaired.

There were six deaths (2.7%), five of which were due to associated injuries (two head injuries, two major liver injuries, one quadriplegia). Only one patient died as a result of vascular trauma. This patient had a transected external carotid artery, bled massively before hospital admission, and was in profound shock on arrival in the emergency department. Angiography was complicated by femoral hematomas in five patients (2.2%).

Discussion

The initial assessment of penetrating injuries of the neck remains one of the most controversial issues in trauma surgery. Many centers advocate mandatory surgical exploration irrespective of signs or symptoms [1–3]. Such a policy is associated with a high incidence of unnecessary operations, ranging from 30% to 89% [1, 3–6]. Had we applied this policy in the current series, our incidence of nontherapeutic operations would have been 86.5%. Other centers practice mandatory exploration for zone II injuries only, citing the simplicity of the procedure in this anatomic area. In the present study only 12.5% of zone II injuries had significant lesions requiring treatment.

Most surgeons practice a policy of selective conservative management based on liberal or even routine use of angiography, endoscopy, and contrast swallow studies [7, 8]. However, these expensive and often invasive investigations have a low yield. Angiography, especially in "asymptomatic" patients, has a low yield and rarely changes the management [9, 10]. In the current study, although 7.8% of "asymptomatic" patients had angiographic abnormalities, none required any form of active treatment. Even when used selectively in patients with proximity injuries or with suspicious clinical signs, the yield of contrast swallow studies in this series was only 2% and 0% for esophagoscopy.

It is obvious that less expensive, less invasive, but safe modalities for evaluating neck injuries are needed. The role of physical examination has been debated for years. Many authors believe that clinical assessment alone is unreliable for detecting significant injuries [1, 8] and that missed injuries are associated with significant mortality [11]. Although some studies suggested that a careful clinical examination is safe and reliable [12–14], most trauma surgeons have remained skeptical. There are three possible reasons for the disparate reported results: First, most of the studies are prolonged retrospective studies. Second, there is no uniform protocol for a careful clinical evaluation; and third, trauma surgeons advocating mandatory exploration or routine angiography may place inadequate emphasis on physical examination.

In a recent large prospective study of 335 patients with penetrating neck trauma, patients were assessed on the basis of a detailed written protocol and an algorithm. Angiography was performed on only seven patients. A total of 269 patients (80%) were required for nonoperative management. Only two of them

Table 5. 83 Patients with 137 injuries.

Injury	Total patients (no.)	GSWs (% of all GSWs)	Knife wounds (% of all knife wounds)	GSW vs. knife *p*
Vascular	48/223 (21.5%)	26/97 (26.8%)	13/89 (14.6%)	0.06
Aerodigestive tract	14/223 (6.3%)	7/97 (7.2%)	3/89 (3.4%)	0.4
Spinal cord	15/223 (6.7%)	13/97 (13.4%)	1/89 (1.1%)	0.03
Peripheral or cranial nerves or sympathetic chain	20/223 (9.0%)	12/97 (12.4%)	4/89 (4.5%)	0.08
Hemo- or pneumothorax	40/223 (17.9%)	15/97 (15.5%)	12/89 (13.5%)	0.86

GSW: gunshot wounds.

Table 6. Incidence of vascular and aerodigestive injury according to zone.

Zone	No. of patients	No. of patients with severe injury	No. of patients with therapeutic operations
I	41	6 (14.6%)	5 (12.2%)
II	105	24 (22.9%)	15 (14.3%)
III	42	10 (23.8%)	2 (4.8%)
Multiple	35	11 (31.4%)	7 (20.0%)

(0.7%) required subsequent surgery for vascular lesions, both of which were detected during the same hospitalization. There were no deaths or significant complications in the rest of the group and no delayed complications on early follow-up (mean 16 days) of 192 patients or late follow-up (mean 48 days) of 111 patients [12]. Because angiography was not part of the routine workup of the patients, it is possible that an unknown number of vascular injuries not requiring treatment were missed. The current study addresses this problem by including in the protocol both a detailed physical examination and routine angiographic evaluation.

On the basis of clinical findings, patients can be classified into two groups: (1) asymptomatic patients and (2) patients with signs and symptoms suggestive of vascular or aerodigestive injuries. The absence of clinical signs reliably excluded significant injuries requiring treatment (NPV of 100% for both vascular and aerodigestive tract injuries).

Many studies have suggested that clinically occult angiographically detected injuries have a benign prognosis without treatment [15–17], but some authors do not accept this concept, particularly for carotid injuries. We suggest that asymptomatic patients, irrespective of the zone of injury, do not require angiography. CFD assessment may be added if the policy of the trauma center is surgical intervention for minimal carotid injuries or occlusive lesions of the vertebral artery. Atteberry et al. [18] suggested that asymptomatic zone II injuries can be safely and accurately managed on the basis of physical examination alone, without angiography or ultrasonography. Similar conclusions and recommendations have been made by other authors as well [9, 19, 20].

Although the absence of clinical signs suggestive of vascular trauma reliably excluded significant injuries requiring treatment (specificity and NPV both 100%) their presence did not reliably predict the patients who would require treatment (overall sensitivity 38.1%). The exception was a group of patients with hard clinical signs (severe bleeding, shock not responding to intravenous fluids, bruit, diminished radial pulse) where treatment was uniformly necessary. A few patients with soft vascular signs had other diagnostic findings that indicated airway injuries (air bubbling through the wound, dyspnea), and the need for surgical intervention was obvious (3.1% of all patients). The last two groups would not have benefited by further vascular assessment via angiography or CFD.

The absence of signs or symptoms suggestive of aerodigestive tract trauma in 152 patients reliably excluded injuries requiring surgical repair (NPV 100%). A total of 64 patients had clinical signs or symptoms suspicious of aerodigestive injuries, but only 10 of them required an operation. Routine evaluation by means of contrast swallow studies, endoscopy, or both had a low yield at significant cost. It is suggested that these studies be reserved for symptomatic or proximity injuries in obtunded patients, in whom clinical examination is not possible. There has been great concern regarding the possible serious implications of missing an esophageal or a laryngotracheal injury. Although this possibility exists for thoracic esophageal injuries, cervical esophageal injuries have a more benign behavior. Studies have shown that small esophageal or tracheal injuries can be safely managed conservatively [21, 22].

In the current study, 127 asymptomatic patients were subjected to angiography at a cost of $254,000 ($2000 per patient), and 11 vascular injuries not requiring treatment were identified. Clinical examination alone would not have missed any significant pathology requiring treatment. It is suggested that asymptomatic patients should not be subjected to angiographic evaluation, provided a careful clinical examination is performed. For surgeons who believe that documentation and perhaps treatment of all minor vascular injuries is essential, CFD is a reliable, inexpensive, noninvasive alternative to contrast angiography. The cost of routine CFD in this group of asymptomatic patients would have been $31,750 ($250 per patient).

It is suggested that symptomatic patients in stable condition should be assessed by means of CFD. Angiography should be reserved for patients with a bruit because of the possibility of therapeutic embolization of a false aneurysm or arteriovenous fistula, those with CFD abnormalities amenable to angiographic embolization, or those in facilities without a noninvasive vascular laboratory.

The absence of signs suspicious of esophageal injury (painful swallowing, subcutaneous emphysema, hematemesis) reliably excluded esophageal trauma in our study. None of the 174 awake, asymptomatic patients had esophageal injuries. It is suggested that only symptomatic or obtunded or intubated patients with proximity injuries are subjected to esophagography.

The algorithm in Figure 2 summarizes our recommendations

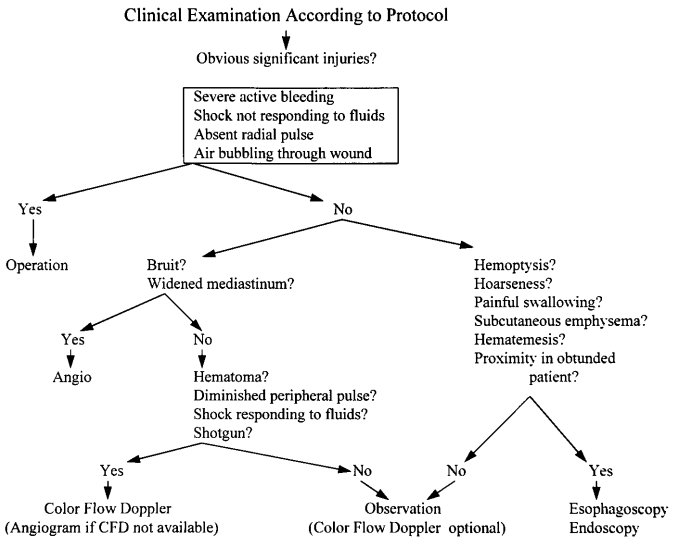

Fig. 2. Algorithm for evaluation of penetrating neck injuries.

for the assessment of penetrating neck injuries. Had we followed this algorithm in the current study, 31 patients (14%) with hard signs diagnostic of vascular or laryngotracheal injuries would have been operated on without any formal diagnostic investigation. Three of the operations would have been nontherapeutic. We would have performed 50 CFD studies, 2 angiograms, and 56 esophagograms; and no significant injury requiring treatment would have been missed. The total cost would have been $30,500 compared to $444,500 for routine angiography and esophagography for proximity injuries.

In conclusion, most patients with penetrating neck injuries can be safely assessed by a careful clinical examination and, in appropriate cases, by CFD and esophagography/endoscopy. CFD is a reliable, inexpensive, noninvasive alternative to angiography. Only a small number of patients require angiographic evaluation. We have now adopted the algorithm in Figure 2 as divisional policy. Given the current pattern and frequency of trauma seen at our institution, we anticipate saving nearly $250,000 a year in the management of penetrating neck injuries alone.

Résumé

Buts: Evaluer le rôle de l'examen clinique, de l'angiographie, de l'imagerie couleur Döppler et d'autres tests diagnostiques dans l'identification des léions vasculaires ou aérodigestives chez les patients ayant eu une lésion pénétrante du cou. Patients et Méthodes: Etude prospective de patients avant une lésion du cou. Tous les patients ont eu un examen clinique soigneux selon un protocole écrit prédéterminé. Les patients stables ont eu une angiographie des quatre vaisseaux, suivie d'un examen Döppler couleur. Une esophagographie et une endoscopie ont été réalisées pour les lésions de voisinage. La sensibilité, la spécificita et les valeurs prédictives de l'examen clinique, de l'examen Döppler et des autres tests diagnostiques ont été évaluées pour leur valeur diagnostique. Résultats: 223 patients ont été analysés. Selon le protocole de l'examen clinique, 176 patients ont eu une angiographie, parmi lesquels 99 avaient eu aussi une imagerie Döppler. Trente-quatre patients (19.3%) avaient une anomalie angiographique, mais seuls 14 d'entre eux (8%) ont nacessité un traitement. La sensibilité de l'examen Dppler a été de 91.7%, la spécificité de 100%, la valeur prédictive positive de 100% et la valeur prédictive négative de 99%. Toutes ces valeurs ont atteint 100% lorsque seules les lésions nécessitant un traitement ont été prises en compte. Aucun des 160 patients sans signe clinique de lésion vasculaire n'ont eu de lésion vasculaire justifiant un traitement (valeur prédictive négative de 100%), bien que l'angiographie, chez 127 d'entre eux ait montré 11 lésions vasculaires ne nécessitant aucun traitement. Les signes cliniques «formels» (hématome expansif, hémorragie active sévère, choc réfractaire à la réanimation liquidienne, pouls diminué, souffle), prédisaient fidèlement une lésion vasculaire nécessitant un traitement. Chez 34 patients (15.2%) avec des signes «mineurs», huit avaient des lésions détectaes angiographiquement, mais seulement un patient relevait d'un traitement. Une esophagographie a été raalisée chez 98 patients pour des lésions de voisinage réelles (49 patients) ou suspectées (49 patients) ; deux montraient des perforations oesophagiennes. Aucun des 167 patients sans signe clinique de traumatisme oesophagien n'avait de lésion oesophagienne nécessitant un traitement. Conclusion: L'examen clinique est fiable pour identifier les patients ayant une lésion pénétrante du cou qui nécessite des investigations vasculaires ou digestives. L'examen Döppler est une alternative sûre l'angiographie. Un algorithme pour 1'évaluation des lésions du con est suggéré.

Resumen

Objetivo: Determinar el rol del examen clinico, la angiografia, la imagenologìa per doppler a color y otros exàmenes diagnòsticos en cuanto a la identificaciòn de lesiones de las estructuras vasculares y aerodigestivas en pacientes con heridas penetrantes del cuello. Pacientes y mètodos: Un estudio prospective de pacientes con heridas penetrantes del cuello. Todos los pacientes tuvieron un examen fisico cuidadoso de acuerdo con un protocolo escrito. Los pacientes estables fueron sometidos a angiografia rutinaria de cuatro vases o a imagenologìa con doppler a color. Se practicò esofagografia y endoscopia para determinar lesiones asociadas. La sensibilidad, especificidad y valor de predicciòn del examen fisico, el doppler a color y otras pruebas diagnòsticas, fueron determinados en la evaluaciòn de las estructuras vasculares y aerodigestivas del cuello. Resultados: 223 pacientes fueron ingresados al estudio. Luego de practicado el examen fisico segiùn el protocolo, 176 pacientes fueron Ilevados a angiografia y en 99 de ellos se realizò imagenologìa con doppler a color; 34 pacientes mostraron anormalidades angiogràficas, para una incidencia de 19.3%, pero sòlo 14 (8%), requirieron tratamiento. La imagenologìa con doppler a color fue practicada en 99 pacientes, con una sensibilidad de 91.7%, una especificidad de 100%, un valor positive de predicciòn de 100% y un valor negative de predicciòn de 99%. Estos valores llegaron al 100% cuando se consideraron saolo aquellas lesiones que requirieron cirugìa. Ninguno de los 160 pacientes sin signos clìnicos de lesiòn vascular presentaron trauma vascular grave que requiriera tratamiento (valor negative de predicciòn 100%), aunque la angiografia en 127 de ellos demostrao 11 lesiones vasculares que no requirieron tratamiento. Los signos mà s "duros" en el examen clìnico (grandes hematomas en expansiòn, sangrado severe active, shock refractario a la administraciòn de lìquidos, pulse radial disminuido, frèmito),

predijeron en forma confiable la presencia de trauma vascular mayor con indicaciòn de tratamiento. Entre 34 pacientes (15.2%) con signos "blandos", 8 presentaron lesiones angiogràficamente detectadas, pero sòlo 1 requiriò tratamiento. Se practicò esofagograma en 98 pacientes per la proximidad de lesiones (49 pacientes) o signos clìnicos sospechosos (49 pacientes), y dos de ellos mostraron perforaciòn esofàgica. Ninguno de los 167 pacientes libres de signos de trauma esofàgico presentò lesiòn esofàgica que requiriera tratamiento. Conclusiòn: El examen fisico es confiable en cuanto a la identificaciòn de pacientes con lesiones penetrantes del cuello que requieren estudios diagnòsticos vasculares o esofàgicos. La imagenologia con doppler a color es una alternativa confiable en relaciòn con la angiografia. Se sugiere un algoritmo para la evaluaciaon inicial de pacientes con heridas penetrantes del cuello.

References

1. Apffelstaedt, J.P., Muller, R.: Results of mandatory exploration for penetrating neck trauma. World J. Surg. *18*:917, 1994
2. Roon, A.J., Christensen, N.: Evaluation and treatment of penetrating cervical injuries. J. Trauma *19*:391, 1979
3. Walsh, M.S.: The management of penetrating injuries of the anterior triangle of the neck. Injury *25*:393, 1994
4. Jurkovich, G.T., Zingarello, W., Wallace, J., Curreri, P.W.: Penetrating neck trauma: diagnostic studies in the asymptomatic patient. J. Trauma *25*:819, 1985
5. Meyer, J.P., Barret, J.A., Schuler, J.J., Flanigan, D.P.: Mandatory vs. selective exploration for penetrating neck trauma. Arch. Surg. *122*: 592, 1987
6. Golueke, P.J., Goldstein, A.S., Sclafani, S.J.A., Mitchell, W.G., Shaftan, G.W.: Routine versus selective exploration of penetrating neck injuries: a radiological prospective study. J. Trauma *24*:1010, 1984
7. Weigelt, J.A., Thal, E.R., Snyder, W.H., Fry, R.E., Meier, D.E., Kilman, W.J.: Diagnosis of penetrating cervical esophageal injuries. Am. J. Surg *154*:619, 1987
8. Sclafani, S.J., Cavaliere, G., Atweh, N., Duncan, A.O., Scalea, T.: The role of angiography in penetrating neck trauma. J. Trauma *31*:557, 1991
9. Beitsch, P., Weigelt, J.A., Flynn, E., Easley, S.: Physical examination and arteriography in patients with penetrating zone II neck wounds. Arch. Surg. *129*:577, 1994
10. Rao, P.M., Ivatury, R.R., Sharma, P., Vinzons, A.T., Nassura, Z., Stahl, W.M.: Cervical vascular injuries: a trauma center experience. Surgery *114*:527, 1993
11. Velmahos, G., Souter, I., Degiannis, E., Mokoena, T., Saadia, R.: Selective surgical management in penetrating neck injuries. Can. J. Surg. *37*:487, 1994
12. Demetriades, D., Charalmbides, D., Lakhoo, M.: Physical examination and selective conservative management in patients with penetrating injuries of the neck. Br. J. Surg. *80*:1534, 1993
13. Demetriades, D., Stewart, M.: Penetrating injuries of the neck. Ann. R. Coll. Surg. Engl. *67*:71, 1985
14. Gerst, P.H., Sharma, S.K., Sharma, P.K.: Selective management of penetrating neck trauma. Am. Surg. *56*:553, 1990
15. Stain, S., Yellin, A., Weaver, F., Pentecost, M.: Selective management on nonocclusive arterial injuries. Arch. Surg. *124*:1136, 1989
16. Frykberg, E.R., Crump, J.M., Vines, F.S., McLellan, G.L., Dennis, J.W., Brunner, R.G., Alexander, R.H.: A reassessment of the role of arteriography in penetrating proximity trauma: a prospective study. J. Trauma *29*:1041, 1989
17. Frykberg, E.R., Vines, F.S., Alexander, R.H.: The natural history of clinically occult arterial injuries: a prospective evaluation. J. Trauma *29*:577, 1989
18. Atteberry, L.R., Dennis, J.W., Menawt, S.S., Frykberg, E.R.: Physical examination alone is safe and accurate for evaluation of vascular injuries in penetrating zone II neck trauma. J. Am. Coll. Surg. *179*:657, 1994
19. Rivers, S.P., Patel, Y., Delaney, H.M., Veith, F.J.: Limited role of arteriography in penetrating neck trauma. J. Vasc. Surg. *8*:112, 1988
20. Menawat, S.S., Dennis, J.W., Laverne, L.M., Frykberg, E.R.: Are arteriograms necessary in penetrating zone II neck injuries? J. Vasc. Surg. *16*:397, 1992
21. Ngakane, H., Muckart, D., Luvono, F.: Penetrating visceral injuries of the neck: results of conservative management policy. Br. J. Surg. *77*:908, 1990
22. Kooper, D.P., Guesta, M.A., Van-Mourik, J.C., De-Vries, N.: Satisfactory results of conservative treatment in traumatic esophageal perforation. Ned. Tijdschr. Geneeskd. *138*:82, 1994

Invited Commentary

Erwin R. Thal, M.D.

Department of Surgery, Southwestern Medical School, The University of Texas, Southwestern Medical Center at Dallas, Dallas, Texas, U.S.A.

Demetriades and his colleagues have designed a prospective nonrandomized study that compares the results of expensive diagnostic studies with careful physical examination. The authors conclude that physical examination is reliable, and therefore many time-consuming, expensive studies can be eliminated. Their paper is yet another of an increasing number of reviews that have reached the same conclusion. These studies are at variance with the older literature, which indicated that 10% to 30% of patients with vascular injuries had a normal physical examination. In today's context those figures were probably falsely elevated, as it has now been shown that many minimal injuries can be managed nonoperatively.

The evidence in this report is convincing, but the study has a few flaws that may influence the results. Twenty-eight patients refused angiography. It may have been better to eliminate those patients from the study. Only 50% of the patients who qualified to have the color flow Doppler examination actually had the study performed. If all those patients had been studied it may have affected the good results that are reported. Only 22% of the patients who had contrast radiography for esophageal proximity underwent esophagoscopy; therefore a comparison could not be made of the two studies. Esophagoscopy was not performed in the two patients with esophageal injury; thus it is difficult to determine if it would have identified the injury. The authors failed to state whether they used flexible or rigid esophagoscopy. The later has been shown to be more reliable for demonstrating cervical esophageal injuries.

As with many trauma reports, the lack of adequate postinjury patient contact is a major problem. The short-term follow-up in this study was 16 days and long-term follow-up only 48 days. Complications following missed vascular injuries may not manifest for several weeks and on rare occasions several months.

Eighty-one patients were lost to follow-up, and it is possible some of these patients may have had a problem not recognized by the limitations of the study. The authors failed to describe what parameters were evaluated at the follow-up visit.

The suggested algorithm will definitely save health care dollars. The total cost savings may be misleading, as the report cites patient charges and not hospital costs, which are considerably less.

There is mounting evidence that minimal injuries, such as intimal tears, tend to heal quickly, although anecdotal cases continue to remind us of the occasional tragic difficulties that occur with missed injuries. Unfortunately, missed injuries in the cervical vasculature can have more dire consequences than missed injuries in the peripheral vascular system where much of this work was done.

This report lends credence to those who advocate a conservative, selective approach to the management of penetrating trauma to the neck. The authors indicate that injuries are more prevalent with gunshot wounds than with knife injuries. A word of caution should be made when one places all penetrating trauma into a single algorithm, as the kinetics of missile injuries are considerably different from those of knife wounds. The strength of this report supports the principle of complete and conscientious bedside clinical evaluation rather than reliance on sophisticated expensive technology. Mature clinical judgment allows the surgeon to individualize the workup and obtain diagnostic studies when indicated. Until we learn more about the long-term natural history of these injuries that are managed nonoperatively, the proper approach to this subject will remain controversial. This study provides important information that helps clear up some of the confusion surrounding the proper management of penetrating trauma to the neck.