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Penetrating Neck Trauma: Sensitivity of Clinical Examination and Cost-effectiveness of Angiography

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PURPOSE: To evaluate penetrating neck trauma for (*a*) sensitivity of the clinical examination as an indicator of clinically significant vascular injury, and (*b*) cost-effectiveness of performing screening diagnostic angiography. **METHODS:** The medical records of all patients with penetrating neck trauma presenting at our institution over 4 years were retrospectively reviewed. Injuries were classified into one of three anatomic zones and classified into four mutually exclusive groups based on the extent of vascular injury: (*a*) no vascular injury; (*b*) minor vascular abnormality; (*c*) major vascular abnormality without a change in clinical management; or (*d*) any injury requiring a change in clinical management. Cost data were also obtained for each patient's hospitalization. **RESULTS:** There were 111 patients with penetrating neck trauma. No statistically significant difference between the sensitivities of the clinical examination or angiography for the detection of vascular injury were detected. Of the 48 patients who had vascular injuries, 45 had an abnormal clinical findings (93.7% sensitivity). None of the remaining 3 patients with vascular injury and normal clinical findings would have had their treatment altered by the results of angiography. The calculated cost of using angiography as a screening tool for vascular injury in patients with normal clinical findings was approximately $3.08 million per central nervous system event prevented. **CONCLUSION:** Our study suggests that in patients with zone II penetrating neck injuries the clinical examination is sufficient to detect significant vascular lesions and that screening angiography may not be indicated. Because our sample size was relatively small and the mean follow-up only 13.3 days, further investigation is needed to demonstrate definitively the lack of usefulness of screening angiography.

Index terms: Neck, injuries; Economics; Angiography, indications

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Increasing constraints on health care resources will require more efficient patient treatment strategies that maintain or enhance patient outcomes. The management of penetrating neck trauma is one clinical problem that offers the potential to reduce costs of care without adversely affecting patient health.

Although most authors agree that patients with clinical evidence of vascular injury should undergo immediate surgical exploration (1), controversy surrounds the treatment of patients without overt clinical evidence of injury to vascular structures. Studies from World War II and the Korean War suggested that mandatory exploration of all penetrating neck trauma was necessary to exclude occult injuries (2–6). In the 1960s, several authors promoted the concept of selective (or expectant) management of such injuries, which included observation in conjunction with endoscopy, bronchoscopy, and angiography (7–11). Monson et al and Saletta et al proposed classifying penetrating neck injuries based on the anatomic zone of the injury (12, 13) but did not attempt to demonstrate statistically significant advantages of such a

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classification. Whereas the exact boundaries of these zones have varied somewhat from author to author, in general, zone I extended from the root of the neck involving the thoracic inlet up to the cricoid, zone II from the region of the cricoid to the angle of the mandible, and zone III above the angle of the mandible involving primarily the base of the skull (Fig 1). The zone injured dictated the patient treatment strategy. Surgical exploration was recommended for asymptomatic patients with zone II injuries, because such surgery was associated with a low morbidity and mortality. Expectant management was recommended for asymptomatic zone I and III injuries, because these areas are difficult to explore and are accompanied by a greater risk of surgical morbidity.

In the 1970s and 1980s, several authors questioned the necessity of surgically exploring all patients with zone II injuries (14–18). Many argued that, instead of performing surgery, it was safe to screen these patients with angiography and panendoscopy, because the vital structures in zone II are superficial. Thus, any major damage would be clinically apparent. The first articles questioning the necessity of angiography did not appear until the late 1980s (19, 20). Although the practice of nonsurgical management of penetrating neck trauma is generally accepted (21–24), it has not been clearly demonstrated that angiography can be abandoned in the clinically asymptomatic patient with penetrating neck trauma.

This article reports a retrospective study of consecutive patients with penetrating neck trauma presenting to a university medical center between 1988 and 1992. The primary purpose of this study was to estimate the sensitivity of the clinical examination as an indicator of vascular injury in patients with penetrating neck trauma. Secondly, the cost-effectiveness of the clinical examination compared with angiography as a screening tool for vascular injury was estimated.

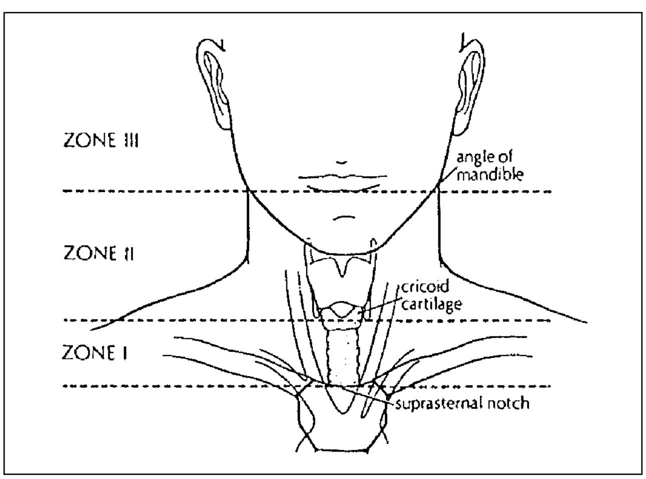

Fig 1. Definition of the three anatomic zones used in neck trauma (from Trunkey and Lewis [39]).

TABLE 1: Clinical criteria indicating vascular injury

1. History of or active arterial bleeding
2. Moderate to large or expanding hematoma
3. Carotid bruits
4. Decreased or absent carotid or upper extremity pulses
5. Neurologic abnormality consistent with central nervous system ischemia
6. Systemic hypotension (systolic blood pressure <90 mmHg)

Methods

Patient Sample

The study setting was a more-than-700-bed urban university hospital with a level I trauma center. All cases of penetrating neck trauma were identified by searching the hospital's computerized databases of radiology and medical records for the years 1988 to 1992, as well as a computerized trauma database from its 1990 inception through 1992. Demographic data and information regarding the patient's injury and hospital care were obtained in a standardized fashion from all cases.

If any of the criteria in Table 1 were present, the patient's clinical examination was considered to indicate the presence of vascular injury. The sensitivity of the clinical examination in assessing the presence of vascular injury was estimated by comparing the findings of clinical examination to those of angiography, surgery, and clinical follow-up.

Categorization of Vascular Injury

Two of the authors (J.G.J. and G.R.P.) classified vascular injuries into one of four categories: (*1*) no vascular injury; (*2*) minor vascular abnormality not impacting on clinical management (mild intimal injury, extrinsic vascular compression); (*3*) major vascular abnormality not requiring a change in clinical management (aneurysm or pseudoaneurysm, large dissection, or occlusion to any of the great vessels or major vessels supplying the intracranial circulation); and (*4*) any vascular injury requiring clinical intervention (Table 2). Stratification according to severity of injury was used for all subsequent statistical analyses.

Determining Cost of Angiography

Direct medical costs for angiography and other resources consumed during a patient's hospital stay were

TABLE 2: Categorization of vascular injury

1.	No vascular abnormality or injury
2.	Minor vascular abnormality without clinical impact
3.	Major vascular abnormality not requiring specific treatment
4.	Any vascular injury requiring clinical treatment

estimated using financial information obtained from the hospital's billing office. Costs of care were estimated by multiplying the detailed charges for all services received by each patient by the hospital department's cost-to-charge ratio.

Statistical Analysis

Descriptive analysis was used for analyzing the collected data. Statistical significance of differences between groups was assessed using the binomial distribution in conjunction with the McNemar Statistic (25). This approach was supported by computing exact binomial 95% confidence intervals for pertinent estimates. These confidence intervals provided estimates used in conducting a sensitivity analysis of the calculated cost-effectiveness ratios.

Results

We initially identified 131 patients with penetrating neck trauma. Complete records were available on 111 patients. Ninety-five (85.6%) patients were male. The mean age of patients was 29.9 ± 11.0 years (range, 12 to 75 years). Eighteen (16.2%) patients had systemic hypotension on initial presentation (systolic blood pressure <90 mmHg), with 9 (18.1%) of these patients having no recordable blood pressure. Sixty-nine (62.2%) patients had gunshot wounds, 30 of which were multiple; 37 (33.3%) had stab wounds, 17 of which were multiple; and 5 (4.5%) patients had shotgun wounds. Nearly half (53, 47.7%), of the patients had injuries confined to zone II, whereas 15 (13.5%) had zone I injuries and 19 zone III injuries. Fourteen (12.6%) patients had injuries to multiple zones. In ten (9.0%) patients, the injured zone could not be determined from the patient's records. Associated injuries were common, with only 40 (36.0%) patients having an isolated neck injury.

A complete clinical examination was documented in only a minority of patients. Documentation of checking for bruits was present in only 6 (5.4%) patients and only 12 (10.8%) patients had a pulse check documented. For the purposes of this analysis, if the status of the pulses and the presence of bruits were unclear from the medical records, the findings were assumed to be normal. This assumption biases the results in favor of performing angiography by decreasing the sensitivity of the clinical examination for vascular injury.

Patients with Normal Clinical Findings and Vascular Injury (False-Negatives)

Forty-eight (43.2%) patients had type 2, 3, or 4 vascular injury (Table 3). Of these 48, 3 (6.25%) had normal clinical findings. However, as described below, none of these three patients with both vascular injuries and normal clinical findings would have had their treatment altered by the results of angiography.

Two of these patients underwent emergency angiography. One patient with a gunshot wound to zone II had a dissection of the external carotid artery and irregularity of the A-1 and M-1 intracranial segments detected by angiography. These irregularities were thought to represent either dissections or emboli. However, the patient was not treated with heparin. His course was complicated by a fever spike that was thought to be secondary to atelectasis. He remained in the hospital for only 5 days and was discharged in good condition. The second patient, who had a gunshot wound to zone I, was found on angiography to have either an aneurysm or a pseudoaneurysm of the subclavian artery. Although it was debated whether the patient should be explored, the vascular surgeons questioned the significance of the abnormality and treated it nonsurgically. This patient had an associated cord injury resulting in paraplegia and was discharged to a rehabilitation facility. The third patient had multiple stab wounds to zone II. She did not undergo angiography but

TABLE 3: Clinical examination findings in patients with and without vascular injury (category 2, 3, or 4)

	Vascular Injury	No Vascular Injury	**Total**
Abnormal clinical findings	45	31	**76**
Normal clinical findings	3	32	**35**
Total	**48**	**63**	**111**

Note.—Sensitivity = true-positives/(true-positives + false-negatives) = 45/48 (.94); specificity = true-negatives/(true-negatives + false-positives) = 32/63 (.51); predictive value positive = true-positives/(true-positives + false-positives) = 45/76 (.59); and predictive value negative = true-negatives/(true-negatives + false-negatives) = 32/35 (.91).

TABLE 4: Patients with discordance of surgery/follow-up with clinical examination/angiography

Patient	Clinical Findings	Angiography	Surgery	Follow-up
B.J.	Abnormal	Mild intimal injury of right vertebral artery and extrinsic compression of left internal carotid artery	Laceration facial artery	. . .
J.K.	Abnormal	Extrinsic compression of right internal carotid artery and right internal jugular vein	Right internal jugular vein laceration	. . .
T.C.	Abnormal	Minimal dissection of left internal carotid artery and external carotid artery	None	Bleeding lingual artery on subsequent angiogram
J.B.	Normal	Subclavian artery aneurysm/pseudoaneurysm	None	. . .

was immediately explored on the basis of wound location. On exploration, a laceration of the external jugular vein was found and repaired. Because the sensitivity of angiography for external jugular lesions is poor, this injury almost certainly would not have been detected by angiography (Table 4).

Patients Undergoing Emergency Angiography with Normal Clinical Findings

Whereas 53 patients had angiography performed at some point during their hospitalization, only 48 had angiograms as part of the initial work-up (Table 5). Eighteen (37.5%) of these 48 had normal clinical findings. It is this group of patients with normal clinical findings who subsequently underwent angiography that warrants examination in greater detail, because these patients potentially obtain no benefit from the angiogram. Fifteen (83.3%) of these eighteen had normal angiograms. Two of the 3 patients with abnormal angiograms were described above (the patient with the M-1/A-1/ external carotid artery abnormalities and the patient with the subclavian artery aneurysm/ pseudoaneurysm). The third patient with normal clinical findings and an abnormal angiogram had a gunshot wound to zones I and II with only extrinsic compression of the external carotid artery. This patient was not explored and was discharged home in good condition. *Thus, none of the 18 patients with normal clinical findings who underwent emergency angiography had their treatment altered as a result of angiography.*

Comparison of Angiography and Clinical Examination in Patients with Vascular Injury

Sixteen (30.2%) of 53 patients undergoing angiography had either a major vascular injury or a vascular injury resulting in a change in treatment. Three of these patients had abnormal clinical findings with a normal or minimally abnormal angiogram, and 1 patient had an abnormal angiogram with a normal clinical examination (Table 6).

Statistical Analysis

Using change in clinical management and follow-up as the reference standard, there was no statistically significant difference between the sensitivities of angiography and clinical examination (P = .625, McNemar Statistic). In fact, in this small series, the trend was for the clinical examination to be more sensitive than angiography for showing vascular injury from penetrating neck trauma to zone II, with a mag-

TABLE 5: Angiography compared with clinical examination for patients with and without category 2, 3, or 4 vascular injury (only patients who had angiography on initial evaluation)

	Abnormal Angiogram	Normal Angiogram	Total
Abnormal clinical findings	25	5	**30**
Normal clinical findings	3	15	**18**
Total	**28**	**20**	**48**

TABLE 6: Comparison of angiography and clinical examination in patients with and without category 3 or 4 vascular injury

	Vascular Injury on Angiography	No Vascular Injury on Angiography	Total
Abnormal clinical findings	12	3	**15**
Normal clinical findings	1	0	**1**
Total	**13**	**3**	**16**

TABLE 7: Clinical examination compared with angiography, surgery, and clinical follow-up for category 3 or 4 vascular injury

	Vascular Injury	No Vascular Injury	Total
Abnormal clinical findings	42	34	**76**
Normal clinical findings	2	33	**35**
Total	**44**	**67**	**111**

Note.—Sensitivity = 42/44 (.95); specificity = 33/67 (.49); predictive value positive = 42/76 (.55); predictive value negative = 33/35 (.94). See Table 3 for calculation formulas of sensitivity, specificity, and positive and negative predictive values.

nitude of difference in sensitivities of .125 (95% confidence interval of 0% to 40%) (25).

Sensitivity of the Clinical Examination

Table 7 summarizes the sensitivity of the clinical examination with respect to the reference tests of angiography, surgery, and clinical follow-up. If a significant vascular injury is defined as either an injury that resulted in a change in treatment or a major vascular injury, then there were only two patients with normal clinical findings in the presence of a significant vascular injury. *The sensitivity of the clinical examination to detect significant vascular injury was .95 (99% confidence interval, .91 to .99) and the specificity .49 (99% confidence interval, .39 to .59)* (26).

Cost Analysis

Complete charge data were available for only 46 (41.4%) patients and for 23 (40.7%) patients who underwent angiography. Hospital charges were subdivided into 24 categories, each having a different cost-to-charge ratio. Using these ratios, charges were converted to estimated costs and totaled for each patient. The Blue Cross–allowed charge was used to calculate the professional-services component of the cost.

Because cost savings could be generated only by not performing angiography in cases with normal clinical findings, the cost data from this subgroup of patients were examined first. Median costs were used because a normal distribution of the data could not be assumed. The median cost of angiography in these patients was $1542 (range, $900 to $2870; mean, $1672), compared with a median total hospital cost of $9697 (range, $1963 to $222 580; mean, $19 217). Thus, on average, angiography accounted for 16% of this group's total hospital costs. In patients with normal clinical findings, no complications, and no associated injuries, the ratio of median angiography/hospital costs was $1650/$5908 (28%). In patients with normal clinical findings and without complications but who may have had associated injuries, the ratio was $1512/$6206 (24%). For all the patients for whom cost data were available, the ratio was $1542/$12 142 (13%).

Cost-effectiveness Analysis

The decision to use any screening test is a function of the tradeoffs among test safety, effectiveness (assessed in terms of morbidity and mortality prevented by the test), and cost (assessed by the cost of the test itself and subsequent induced interventions). One method to estimate the expense of a screening test is to determine how much money it costs to save a life and a year of life. Taking a societal perspective, the first task is to estimate the magnitude of the problem in the United States. This can be represented as follows:

1) No. of patients in United States with occult vascular injury = (no. cases of penetrating neck trauma in United States) × (% with normal clinical examination) × (% of those with abnormal clinical examination who had a major vascular abnormality).

Whereas a precise figure for the total number of cases of penetrating neck trauma in the United States is difficult to determine, the reported range in 1987 was between 13 000 and 25 000 (27). Thus, a reasonable first order of magnitude estimate for the number of injuries is approximately 18 000. From our study, 30% of these patients would be expected to have normal clinical findings and 5% of those with normal clinical findings a major vascular abnormality. Because the natural history of occult vascular lesions is unknown, it is extremely difficult to estimate accurately the percentage of these patients who will progress to a major adverse central nervous system event (stroke or death). Estimating that 1% of these patients will have a major adverse central nervous system event if unrecognized and untreated, we arrive at the following calculation:

2) No. of patients in United States with occult vascular injury = 18 000 × .3 × .05 = 270 patients/year.

3) $270 \times .01 = 2.7$ patients with adverse central nervous system event from occult vascular injury/year.

Assuming the worst case, that all patients who had clinically occult vascular lesions would have their outcome favorably altered by detection, approximately three patients per year would benefit from screening angiography.

The cost portion of the equation can be thought of as follows:

4) cost of screening angiography in the United States per year = (no. of screening exams/yr) × (median cost/exam).

We recognize that this is only a partial estimate of medical cost, because our calculations do not include the cost of induced tests, the cost of adverse effects of angiography, the cost of health care and rehabilitation prevented by screening, or the cost of treating diseases that would not have occurred if the patient had not lived. From equation 2 above, we see that there are approximately 5400 screening examinations performed per year in the United States ($18\,000 \times 0.3 = 5400$). At the hospital in this study, the median cost of angiography was $1542. Inserting these numbers into equation 3, we arrive at:

5) 5400 exams/year × $1542/exam = $8 326 800/year.

Because all patients already have a history taken and receive a physical examination, there are no additional costs for this alternative to screening angiography. Thus, the above costs all represent incremental increased costs of angiography. To arrive at a measure of cost-effectiveness, we divide equation 5 (the incremental cost of screening angiography) by equation 3 (the incremental benefit of screening angiography), yielding an estimate of an additional $3.08 million per additional central nervous system event prevented.

The true cost of missing an injury is difficult to calculate precisely. The natural history of a focal intimal dissection (or mild intimal injury) of the carotid or vertebral artery remains poorly characterized. Most of these lesions likely resolve without any treatment (28, 29), yet certainly some of these patients have strokes. Definitive data do not yet exist to identify which of these patients benefit from anticoagulation. The type of treatment for intimal dissection also is hotly debated. Heparin, coumadin, and aspirin all have been suggested as treatments, but no clear consensus yet exists (30–33). The cost of health care and rehabilitation for a 35-year-old person who had a stroke and lives until age 70 is approximately $1 050 000 (34). If one assumes that all adverse central nervous system events could be prevented by early detection and treatment, the savings of medical costs attributable to the prevention of stroke would be $1 050 000 × 2.7 = $2 835 000. This can be subtracted from the yearly cost of angiography to yield a net cost of $5 491 800. Dividing by 2.7 adverse events per year, we arrive at the somewhat smaller but still considerable amount of $2.03 million per additional central nervous system event prevented.

Sensitivity Analysis

There are two variables in our study that most likely have a major impact on the conclusions if their values are altered: (*a*) the incremental sensitivity of angiography with respect to the clinical examination; and (*b*) the incremental cost of angiography compared with the clinical examination. These variables were subjected to sensitivity testing.

The 99% confidence interval was used as the range for the sensitivity analysis. The results of this sensitivity analysis of the clinical examination are shown in Table 8A. Similarly, varying the cost of angiography yields the results in Table 8B.

The analysis also may be affected by variation in the proportion of patients with normal clinical findings (Table 8C). One might expect a higher percentage of patients to have an abnormal examination in other settings, such as wounds sustained from more destructive weapons.

Finally, there is uncertainty in the percent of adverse central nervous system events that would occur in patients with a vascular injury. We varied this percentage fivefold in either direction (Table 8D).

The above sensitivity analyses demonstrate that several variables may have a significant impact on the final cost-effectiveness estimates as their values are varied. This indicates the need for more precise data with respect to both the scope and costs of this problem.

TABLE 8: Sensitivity analyses

A: Variable Sensitivity of Clinical Exam			
Sensitivity of Clinical Exam	No. Adverse CNS Events/Yr	Cost of Screening	Incremental C/E
.91	4.86	$9 477 000	$ 1 950 000
.95	2.70	$9 477 000	$ 3 510 000
.99	0.54	$9 477 000	$17 550 000

B: Variable Cost per Angiogram		
Cost per Angiogram	Cost of Screening/Yr	Incremental C/E
$771	$ 4 163 400	$1 542 000
$1 542	$ 8 326 800	$3 510 000
$3 084	$16 653 600	$6 168 000

C: Variable % Normal Clinical Exams			
% with Normal Clinical Findings	No. Adverse CNS Events/Yr	Cost of Screening	Incremental C/E
0.1	0.9	$8 326 800	$9 252 000
0.3	2.7	$8 326 800	$3 084 000
0.5	4.5	$8 326 800	$1 850 400

D: Variable % Major Adverse CNS Events with Unrecognized Vascular Injury			
% with Major CNS Event	No. Adverse CNS Events/Yr	Cost of Screening	Incremental C/E
0.2	0.54	$8 326 800	$15 420 000
1.0	2.7	$8 326 800	$ 3 084 000
5.0	13.5	$8 326 800	$ 616 800

Note.—CNS indicates central nervous system; C/E, cost-effectiveness ratio.

Discussion

Although the treatment of patients with penetrating neck trauma will continue to stir controversy, this study raises serious questions regarding the traditional treatment of these patients. Our results suggest that the clinical examination is an excellent screening "test" and that angiography may not be required for patients with zone II penetrating trauma to the neck and normal clinical findings. The criteria listed in Table 1 may serve as a useful checklist for the clinician who is assessing patients with these types of injuries. There are, however, several important limitations to this study.

First, the sample size in this study is small, which limits both the power to test hypotheses and our ability to exclude the acceptance of a false null hypothesis (type II [β] error). Given the estimated sensitivity of clinical examination with respect to angiography, for a study to be able to demonstrate the lack of benefit of angiography with a power of at least 80%, a cohort of more than 300 patients is required.

Second, this study, like others involving trauma patients, suffers from a lack of clinical follow-up. Outcome is best assessed by a clinical follow-up of months to years, because delayed complications of occult vascular injuries, such as embolization from an undetected dissection or rupture of a pseudoaneurysm, are a concern. Mean clinical follow-up in this study was only 13.3 days.

Third, this study suffers the same limitations of all retrospective chart review studies. Inadequate documentation may produce a biased result. For example, the presence or absence of a bruit often was not specifically noted. Therefore a "negative examination" by chart review may not be completely accurate. We tried to account for this by assuming that, unless specifically documented, the history and physical findings were normal. As noted previously, this assumption conservatively biased the results by decreasing the sensitivity of the clinical examination for vascular injury.

Fourth is the question of whether our results can be generalized to other centers. The sensitivity of the clinical examination is greatly dependent on its thoroughness. Undoubtedly, not all centers perform identical examinations.

Fifth, the cost of a missed injury is difficult to calculate. Because the natural history of these lesions is poorly defined and treatment is controversial, the number of preventable strokes is uncertain. As a consequence, the costs resulting from preventable strokes are also uncertain.

Our results are supported by the work of others (19, 20, 35–38), whose studies suggest that angiography is not superior to the clinical examination in detecting vascular injury. Whereas angiography is almost certainly superior to the clinical examination at finding certain types of injury, such as focal intimal dissections, the clinical significance of these lesions is debatable. Thus, the clinical examination may work as a high pass filter, with ultimately only the important injuries warranting angiography.

Conclusions

The results of this study suggest that the clinical examination has excellent sensitivity at showing clinically significant vascular injury in patients with penetrating neck trauma. Moreover, the cost of performing screening angiography in patients who have no clinical evidence of vascular injury adds significantly to the cost of hospitalization. Although we do not advocate being "penny wise and pound foolish," appropriate use of expensive resources is more essential now than ever. Given the high cost and lack of superiority over clinical examination's sensitivity, the use of angiography as a screening tool in patients with penetrating neck trauma and normal clinical findings must be questioned. A prospective, multiinstitutional study, with the goal of ultimately designing minimum criteria to evaluate persons with penetrating neck trauma, would overcome the major limitations of our study. Further investigation must focus on incremental diagnostic accuracy, changes in clinical management, improvement in patient outcome, and economic import.

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