

Continued experience with physical examination alone for evaluation and management of penetrating zone 2 neck injuries: Results of 145 cases

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Purpose: Our preliminary experience with physical examination alone in the evaluation of penetrating zone 2 neck injuries for vascular trauma was previously reported in 28 patients over a 2-year period (1991-1993). The purpose of the current study was to examine the results of this approach in a much larger group of patients over an 8-year period.

Methods: The medical records for all patients admitted to our level I trauma center (all of them entered into our prospective protocol) between December 1991 and April 1999 with penetrating zone 2 neck trauma were reviewed for their initial presentation and any documented vascular injury.

Results: A total of 145 patients made up the study group; in 30 of these patients, the penetrating trajectory also traversed zone 1 or 3. Thirty-one patients (21%) had hard signs of vascular injury (active bleeding, expanding hematoma, bruit/thrill, pulse deficit, central neurologic deficit) and were taken immediately to the operating room; 28 (90%) of these 30 patients had either major arterial or venous injuries requiring operative repair (the false-positive rate for physical examination thus being 10%). Of the 114 patients with no hard signs, 23 underwent arteriography because of proximity of the injury to the vertebral arteries or because the trajectory included another zone. Of these 23 arteriograms, three showed abnormalities, but only one required operative repair. This case had no complications relating to the initial delay. The remaining 91 patients with no hard signs were observed without imaging or surgery for a minimum of 23 hours, and none had any evidence of vascular injury during hospitalization or during the initial 2-week follow-up period (1/114; false-negative rate for physical examination, 0.9%).

Conclusions: This series confirms the earlier report indicating that patients with zone 2 penetrating neck wounds can be safely and accurately evaluated by physical examination alone to confirm or exclude vascular injury. The missed-injury rate is 0.7% (1/145) with this approach, which is comparable to arteriography in accuracy but less costly and non-invasive. Long-term follow-up is needed to confirm this management option. (*J Vasc Surg* 2000;32:483-9.)

The management of penetrating zone 2 neck injuries without hard signs of vascular injury has been controversial for more than half a century. The arguments have changed over the years, but there is

no uniformly accepted management plan despite hundreds of articles on the subject. Although it is a reasonable option in military situations,¹⁻³ few people still advocate mandatory cervical exploration in asymptomatic patients.⁴ The routine use of arteriography (AG), which has been termed "selective management," is currently the most common practice in most trauma centers.⁵⁻⁸ Others advocate the use of duplex ultrasound scanning (US) to selectively manage patients.⁸ One of the first prospective studies to evaluate the use of physical examination (PX) alone for confirming or excluding vascular injury in this setting was reported from our institution.⁹ This approach was found to be safe and reliable in deter-

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Competition of interest: nil.

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mining whether surgery for vascular repair was needed in a small group of patients. On the basis of these preliminary findings, management of all penetrating zone 2 wounds of the neck has been based solely on PX at our institution during the past 8 years.

The purpose of the current study was to determine whether our initial results could be confirmed over this longer interval in a larger group of patients.

METHODS

This study examines the results of the prospective use of PX alone to confirm or exclude surgically significant vascular trauma in all penetrating zone 2 neck injuries that presented to Shands Jacksonville, Jacksonville, Fla, from December 1991 through April 1999. The hospital is an urban level I trauma center with more than 3500 annual trauma admissions. The study protocol was approved by the Institutional Review Board for human subjects.

The boundaries of zone 2 of the neck are described as the angle of the mandible cranially and the cricoid membrane caudally. Each adult patient (aged 18 years or older) with a penetrating neck injury to this region was carefully examined for definite (hard) physical signs that are widely recognized as accurately reflecting vascular injury. This examination was always done by a senior resident and attending surgeon on presentation of the patient to the trauma center. In the rare instance of disagreement, the attending surgeon's decision was final. These hard signs (ie, positive PX findings) include active bleeding, expanding hematoma, a bruit or thrill over the wound, pulse deficit, and a central neurologic deficit corresponding to the side of the injury. Patients without these signs (ie, negative PX findings) were admitted and underwent serial PX for a minimum stay of 23 hours. The development of any hard signs during this time or thereafter mandated immediate surgical exploration or AG.

The findings from plain radiographs of the neck and chest, esophagrams, and endoscopy were used as indicated to evaluate nonvascular structures but were not part of the prospective protocol. On discharge, each patient was counseled to return immediately if any definite signs of vascular injury occurred; all patients were given follow-up clinic appointments.

RESULTS

A total of 145 adult patients were admitted with penetrating neck trauma to zone 2 during the 8-year period. Mechanisms of injury were as follows: gunshot wound, 52; stab wound, 90; other penetrating

object, 3. Each of 30 injuries (21%) also involved zone 1 or zone 3.

Thirty-one patients (21%) had hard signs of vascular injury and were taken immediately to the operating room. Twenty-eight (90%) of these patients had either major arterial or venous injuries requiring repair. One of the remaining three patients with hard signs had a thyroid laceration that was actively bleeding; this was considered a false positive inasmuch as it did not involve a major artery. Another patient had a bleeding tracheal and esophageal injury, and a third patient had bleeding from small unnamed vessels. Strictly speaking, the overall false-positive rate was 10%; however, two of the three patients in this group required exploration for injuries to associated neck structures—namely, the thyroid and the esophagus. The unnecessary exploration rate in this group was thus only 3% (1/31).

Of the 114 patients (79%) with no hard signs, each of 23 underwent AG because of proximity of the injury to the vertebral artery (five patients) or because the trajectory included another zone (18 patients). Three (13%) of these arteriograms showed abnormalities, but only one small laceration of the common carotid artery required operative repair (1/23; 4.3% false-negative rate); the other two abnormalities were an internal carotid and a vertebral artery smooth narrowing, neither of which required any intervention or developed further problems (Table I). The 91 remaining patients without hard signs were observed without imaging or surgery for a minimum of 23 hours. During the observation period, none of these patients had hard signs that required surgical exploration or AG. Forty-two patients (46%) kept their follow-up appointments, and none had any signs of vascular injury at 2-week follow-up examinations. Overall, the management protocol resulted in only one (0.9%) of 114 patients having a missed significant injury. Although they were not followed up beyond their initial visits, no patient treated during the period has returned to our institution for a late-developing problem related to the neck injury, nor has any of the patients been reported to us as having been treated at an outside hospital after discharge.

DISCUSSION

This report represents an extended study of a prospective protocol which initially indicated that PX alone is a safe and reliable means by which to evaluate patients presenting with penetrating wounds to zone 2 of the neck for vascular injury.⁹ In that initial series, only 28 asymptomatic patients

Table I. Outcomes in absence of hard signs of vascular injury

Observation: 91
No injury at 24 hours
No injury at 2-wk follow-up (46% compliance)
AG: 23
Negative: 20
Positive: 3
ICA narrowing, no treatment: 1
Vertebral artery narrowing, no treatment: 1
CCA laceration, operative repair: 1

CCA, Common carotid artery; ICA, internal carotid artery.

were evaluated on a prospective trial basis to determine whether this approach was indeed feasible and safe. The stimulus to attempt this type of management came from an earlier study from our center that was reported in 1992.¹⁰ This was a retrospective review of 110 patients with penetrating zone 2 neck injuries, and it identified only one patient (0.9%) as having a significant major arterial injury requiring surgery that was not predicted by PX. At that time, standard management included either AG or surgical exploration, these being considered the only acceptable methods of evaluating such wounds for vascular injury. The confirmation of the safety and accuracy of PX in this setting, which this longer-term study documents, represents a paradigm shift toward a simpler, less costly, equally accurate, and widely applicable method of determining the proper management of these patients.

Management evolution. Until the 1950s, penetrating wounds to zone 2 of the neck were managed conservatively with observation alone unless active life-threatening hemorrhage was present. These bleeding arterial injuries were ligated, and the resulting incidence of stroke was approximately 30%.^{11,12} Direct surgical repair was first attempted and shown to be feasible during the Korean conflict.¹³ The first large civilian series, that of Fogelman and Stewart¹⁴ in 1956, clearly showed the benefit of direct arterial repair in comparison with ligation and demonstrated that improved outcome was directly related to the time between injury and repair.¹⁴ This landmark study established the original approach of mandatory exploration of all neck wounds penetrating the platysma, the unfounded assumption being that any missed arterial injury, even in an asymptomatic patient, would inevitably lead to devastating consequences.

Further refinement of this approach occurred as a result of a paper from Cook County Hospital in 1969; in this report, the neck was for the first time divided into three zones.¹⁵ The authors recom-

Table II. Studies recommending PX alone in management of penetrating zone 2 neck injuries

Study	No. of penetrating zone 2 injuries			No. of missed injuries (%)
	Total	With hard signs or explored	With no hard signs	
Biffel et al ^{24*}	208	80	128	1 (0.9)
Beitsch et al ²⁵	178	42	136	1 (0.7)
Jarvik et al ²⁶	111	45	66	0
Demetriades et al ^{27*}	335	66	269	2 (0.7)
Gerst et al ²⁸	110	52	58	0
Byers et al ²⁹	106	62	44	0
Rivers et al ³⁰	23	1	22	0
Sekharan et al*	145	31	114	1 (0.8)
Totals	1216	379	837	5 (0.6)

*Prospective study.

mended AG in injuries to zones 1 and 3 but continued to agree with the concept of mandatory exploration for zone 2. This approach persisted for many years despite a negative exploration rate of up to 56%.¹⁶ AG became widely available in the late 1970s, and a review of studies using this diagnostic technique showed it to be highly accurate and comparable or superior to surgical exploration in morbidity and mortality.¹⁷ In less than 10 years, AG had replaced exploration as the primary means by which penetrating zone 2 injuries were evaluated for vascular trauma.^{18,19}

Current controversies. Studies published in the late 1980s and early 1990s concerning the use of PX alone in managing penetrating proximity injuries of the extremities led some centers to consider adapting this strategy for zone 2 injuries.^{20,21} Data clearly showed that in the extremities, the absence of hard signs of vascular injury accurately excluded arterial injuries needing surgical repair. Two early articles hinted at expanding the use of PX alone in evaluating zone 2 wounds for vascular injury, but they failed to gain any widespread support.^{22,23} The reason for the reluctance to extend this type of management to the neck was concern that any missed injury could result in a stroke, which could be life-threatening, rather than a limb-threatening complication.

During the past decade, however, multiple studies involving more than 1200 patients have examined the use of PX alone to detect hard signs of vascular injury requiring surgical repair in zone 2 of the neck²⁴⁻³⁰ (Table II). These series have shown PX to have an accuracy of greater than 99% in diagnosing significant vascular injuries. The missed-injury rate is comparable to that of AG; moreover, PX is associat-

ed with substantially less time, lower costs, and the involvement of fewer personnel.^{29,30}

At our institution, the total charge for AG, including professional fees, is a minimum of \$1500.00. Thus, in this study, at least \$136,500 in charges were avoided through the use of PX as a method of evaluating 91 patients, and there was not a single adverse consequence. One study estimates the cost of using AG in detecting cervical vascular injuries in patients with no physical findings to be approximately \$3.08 million per central nervous system event.²⁶

Some centers advocate the use of duplex US to determine the presence of vascular injuries in penetrating trauma.^{8,31-34} The rationale for US is the same as that for AG or surgery—namely, that arteries must routinely be imaged. Although they are noninvasive and less costly (\$400-\$500 per study), such examinations still require skilled technologists to accurately interpret the results, and these are personnel not usually available after normal daytime hours. Our earlier experience with US, though limited to only 18 patients, showed it to have no benefit.⁹ The current study shows imaging to be unnecessary, and to date, no study has shown US to be superior to the much less costly modality of PX alone.

Minimal injuries. Penetrating trauma can cause occult arterial injuries that show no hard signs of vascular injury in approximately 10% to 15% of cases.^{20,21,35-37} These types of injuries include smooth narrowings, intimal irregularities, and small pseudoaneurysms and arteriovenous (AV) fistulas. If AG is not obtained routinely, these minimal injuries will not be recognized. In the extremities, the risk that such injuries will deteriorate into significant lesions requiring surgery has been well documented; they will do so approximately 10% to 15% of the time.^{20,21,35-37} For the overall total population of patients with penetrating trauma injuries, this amounts to only 1% to 3%.^{20,21,35-37} Short-term and long-term studies have shown that smooth narrowings almost never deteriorate. Intimal irregularities rarely worsen, and pseudoaneurysms and AV fistulas deteriorate most often.^{20,21,38} This arterial deterioration usually develops within several weeks after the injury and fortunately can usually be repaired with no additional morbidity. Limited evidence shows these injuries to have a similar benign natural history in the neck.^{39,40} It can be assumed that PX will miss these minimal injuries, but the overall results of this study indicate that they are not clinically significant, and they therefore do not justify the expense that is necessarily associated with their detection.

Exceptions. There are a few exceptional situations in which AG may still be required in penetrating zone 2 injuries. When the trajectory of the penetrating agent traverses two zones, then AG may be useful in determining the presence of arterial injuries in zones 1 and 3, where PX is less reliable. Evidence suggests an increased probability of multiple injuries when the penetrating agent crosses the midline and involves both sides of the neck.⁴¹ Patients with associated head injuries may also require AG if an adequate PX is not possible because the patient is unresponsive. Furthermore, if the path of the penetrating agent appears to be in proximity to the vertebral arteries, AG might be indicated. Most vertebral injuries do not require repair, but endovascular treatment is often the best approach to these injuries, and AG is necessary for this.^{42,43} Patients suffering shotgun blasts to the neck also require AG because of the multiple missile paths, which can cause a variety of vascular injuries. In addition, small hospitals with limited personnel resources may need to continue to use AG or US to determine immediately whether surgery is needed.

Long-term follow-up. The main limitation of this study is the lack of long-term follow-up for this approach to penetrating zone 2 neck injuries. Data acquired from 5 to 10 years of follow-up on penetrating extremity injuries, however, fail to show any long-term problems developing from the careful observation of asymptomatic patients.³⁸ It is clear that the absence of hard signs reliably excludes those vascular injuries that will require surgical repair and that any minimal arterial injuries have a largely benign natural history. Most of the injuries that deteriorate do so within the first 2 weeks after the trauma, and nearly all of them present in the first 3 months. Anecdotal reports of pseudoaneurysms or AV fistulas presenting years after penetrating injuries have been published⁴⁴⁻⁴⁶; in almost all of these cases, however, the patients have had no documentation of the physical findings on initial presentation, and they have undergone successful repairs without morbidity despite the delay.

In trauma cases, follow-up studies are able to achieve only a limited (20%-50%) success rate in reevaluating these patients.^{38,47-49} All patients within this study were advised about the possible development of signs of vascular injury. In addition, most of the patients live in proximity to our institution. To date, not a single person during the 8-year period has returned with a delayed complication as a result of the use of PX alone in determining the need for surgical repair. Attempts are underway to reeval-

uate and reexamine patients in this study after 1 to 2 years. Centers in which "selective management" with either AG or US is used rarely report any long-term follow-up, even with respect to patients undergoing surgery.

Future considerations. This study and others provide compelling evidence that PX alone is a safe and effective approach to both confirming and excluding surgically significant vascular injury after penetrating zone 2 neck trauma. In the future, direct discharge from the trauma center (ie, with no observation period) of patients with negative PX findings may become a viable consideration. It is our hope and belief that over the next several years the use of PX alone will become the standard management option. Although blinded studies are impossible, we encourage prospective, randomized trials by other trauma centers currently using AG or US in their selective management.

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DISCUSSION

Dr Kenneth McIntyre (Dallas, Tex). Good morning, members and guests. The authors of the paper you just heard propose that the correct management of penetrating zone II neck injuries, that is, observation versus surgical exploration, can be predicted by a good physical examination. Furthermore, they propose that patients with penetrating zone II neck injuries who present with no hard signs of vascular injury may be safely observed without the need for diagnostic arteriography or mandatory surgical exploration. From the results of this study, the authors conclude that physical examination alone was a safe and viable means by which to manage patients presenting with penetrating injuries to zone II of the neck. Before we accept this assumption, however, we should examine the work carefully, because I believe there are certain methodological errors that would lead one to be wary of this conclusion. I will try to elucidate these for you.

First of all, I think there is a number's flaw. Apparently 30, which is 21% (1 in 5 of these injuries), also involved zone I or zone III in addition to zone II of the neck. If an injury truly involves more than one zone, certainly these patients should not be included in an analysis of isolated zone II injuries as the management and outcome vary considerably. Twenty-one percent presented with hard signs of vascular injury, and all underwent immediate surgical exploration. The decision to manage this group surgically is straightforward, and I congratulate the authors on doing the right thing, although the outcomes from their surgical management are not included in the manuscript. Twenty percent of patients without hard signs underwent arteriography, but it is not clear from the manuscript how many underwent the study because of proximity to the vertebral arteries and how many underwent the study because the trajectory included another zone.

Secondly, I think there is an error of omission in the protocol for diagnostic tests other than angiography in

that "the use of plain radiographs of the neck, chest x-rays, esophagograms and endoscopy were performed as indicated to evaluate nonvascular structures but were not part of the prospective protocol." Penetrating neck trauma may cause injury to other structures besides blood vessels (eg, esophagus, trachea, thoracic duct, and mandated surgical exploration and repair).

Thirdly, and probably most importantly, the follow-up was poor. Only 46% returned for a 2-week follow-up appointment, and none were seen thereafter.

Finally, no duplex examinations were performed either at the time of injury or during the follow-up appointment.

I hope the authors will be able to shed some light on these observations, and I offer the following questions. First, why did you include patients with injuries that involved more than one zone in your study? We know that the outcome from zone I and zone III injury evaluation and outcome are different. Secondly, I was surprised that you recommended arteriography for patients without hard signs and proximity to the vertebral arteries when it is known that most vertebral injuries do not even need to be repaired. Why was arteriography recommended for proximity to the vertebral arteries? Arteriography was performed in 23 patients, and yet 30 patients had an injury that involved more than one zone. In your discussion you advise that patients with injuries that involve more than one zone should undergo arteriography, and yet only three quarters had this test performed. Why have you not followed your own recommendations? Thirdly, other diagnostic procedures were performed that helped you decide when to operate. How many nonvascular injuries were discovered from examinations other than arteriography that required surgical repair? Finally, you admit that there are anecdotal reports of carotid injuries that go initially undiagnosed and present months to years later with symptoms of cerebral ischemia. Why did you not elect to perform

duplex scans on patients during the follow-up examination to help you identify missed injuries?

In summary I would urge caution in adopting the authors' advice. Like other trauma-related studies, the follow-up is very limited, and the authors offered no duplex data to support their contention that no injury truly occurred. Without reasonable follow-up, including duplex imaging, we cannot be so confident. Clearly, every patient with a penetrating zone II neck injury does not require surgical exploration; however, prudent use of duplex scanning, endoscopy, and other adjunctive radiologic tests may provide a more advisable algorithm for the evaluation of these challenging patients than physical examination alone.

I want to thank the program committee for the opportunity to discuss this interesting paper. Thank you.

Dr Joyce Sekharan. Thank you, Dr McIntyre. First of all, we did include the other vascular injuries to the other zones because the zone II was very easily amenable to physical examination, and we felt confident that we could include other injuries that involved this zone, also. There are papers out there that even advocate conservative management for zone I and zone III injuries and show that physical examination can be used to manage them.

The basis of arteriography and the need for arteriography were clinical evaluations made by the attending surgeon. Not all injuries that appeared to penetrate zone III or zone I required angiography as based on the attending surgeon's recommendations.

While most vertebral injuries are not amenable to operative repair, they are amenable to angiographic intervention, and this is also documented in the literature. This is a primary treatment modality. If there is a vertebral artery injury, it would behoove us to take the patient to angiography and have angiographic intervention done for these patients.

We elected not to use duplex ultrasound in these patients for four reasons. In our paper published by Linda Atteberry in 1994, we showed that duplex ultrasonography had the same results as arteriography and the same rate of missed injuries. Therefore, we did not find any superiority to arteriography or ultrasonography to physical examination. There are other papers in the literature that support this. No one has ever shown that ultrasound is superior to arteriography, and no one has ever shown that ultrasound is superior to physical examination. In addition,

ultrasonography requires an experienced technician, and there is a definite time delay when it has been shown that there is no superiority to using this modality. There is no reason to add extra time delay or an additional cost of ultrasound. Ultrasound at our institution costs about \$500.

The other injuries to the aerodigestive tract are being evaluated independently at this time by us, and we are hoping to publish this in the future. We had two esophageal injuries and six tracheal injuries. We are not advocating at this point from our paper that these injuries should be managed by physical examination, though there are other papers in the literature that advocate management of these injuries by assessing for signs of crepitus or other signs on physical examination. We have evaluated these other injuries as necessary by the modalities that you have described.

Dr Frank Stoneburner (Richmond, Va). I enjoyed your paper. As residents at MCV in 1987, Jerry Mendez and I retrospectively reviewed several hundred penetrating neck injuries at MCV. We found a disturbing number of late presentations of pseudoaneurysms. I think it was a series of about 10 pseudoaneurysms from false passage. In light of this information, do you still feel that follow-up carotid duplex is unnecessary? Thank you. Good paper.

Dr Sekharan. As you can see our follow-up was about 46% for those observed, and that is actually a very good follow-up rate in trauma literature. We chose not to evaluate these patients by duplex ultrasound. Most of these injuries would eventually come back to us. In our institution where there are primary caregivers for our patient population, we have not seen anyone come back to us with any signs of vascular injury in a delayed presentation. It is a thought to incorporate duplex ultrasound in a follow-up, but we have chosen not to do it and we have not seen any adverse outcomes.

Doctor. I am just curious what people are doing in the audience. If you have an isolated gunshot wound, zone II, right now, who would get arteriograms, without hard signs? An isolated gunshot wound, zone II, no hard signs—who would get an arteriogram? Who would get a duplex scan? And who would rely on physical examination alone? (*show of hands*) Okay. Interesting. Good presentation. Thank you.