Clinical Practice Guideline: Penetrating Zone II Neck Trauma

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STATEMENT OF THE PROBLEM

Penetrating wounds of the neck are common in the civilian trauma population. Risk of significant injury to vital structures in the neck is dependent on the penetrating object. For gunshot wounds, approximately 50% (higher with high velocity weapons) of victims have significant injuries, whereas this risk may be only 10% to 20% with stab wounds.

The management of injuries to the neck that penetrate the platysma is dependent on the anatomic level of injury. The neck has been divided into threes zones. Zone I, including the thoracic inlet, up to the level of the cricothyroid membrane, is treated as an upper thoracic injury. Zone III, above the angle of the mandible, is treated as a head injury. Zone II, between zones I and III, is the area of controversy. Because of the density of vital structures in this zone, multiple injuries are common[1] and can affect length of stay.[2] Mortality, particularly for major vascular injuries may reach 50%.[3] Delayed complications such as pseudoaneurysms or arteriovenous fistulae can affect long-term outcomes.[4] Appropriate and timely

management of these injuries is critical. For the patients with hard signs of significant injury, including active hemorrhage, expanding hematoma, bruit, pulse deficit, subcutaneous emphysema, hoarseness, stridor, respiratory distress, or hemiparesis, immediate operative management may be indicated. Controversy arises over management of the patient without significant symptoms. The management of these patients has been evolving from an era of mandatory exploration to an era of more selective management. Mandatory exploration, while seemingly safe and conservative, led to many nontherapeutic operations. This fact, along with advances in technology, such as high resolution computed tomography (CT), may eliminate the need to explore the neck to determine whether there are injuries. Also during the time that technology had been advancing, many reports have documented the safety of selective management of neck injuries that penetrate the platysma. This experience has demonstrated that physical examination may be reliable and that not all injuries to vital structures in the neck need surgical intervention for repair. This guideline was therefore initiated to examine the specific roles of mandatory exploration versus selective management based on physical examination and current imaging technologies for penetrating neck trauma.

Goals of the Guideline

This guideline is designed to answer the following questions regarding the management of penetrating injuries to zone II of the neck that penetrate the platysma.

1. Is mandatory operative management or selective operative management appropriate?
2. Can duplex ultrasonography (US) or CT angiography rule out an arterial injury in patients with no hard signs of vascular injury on physical examination, thereby making arteriography unnecessary?
3. Are both contrast studies (barium or gastrograffin swallow) and esophagoscopy needed to safely rule out esophageal injury?

4. Is physical examination sensitive enough to rule out injuries to vascular structures or the aerodigestive tract?

PROCESS

The process used by this committee was developed by the Practice Management Guidelines Committee of the Eastern Association for the Surgery of Trauma (www.east.org). The committee agreed on the questions to be considered. Literature for review included the following terms: human, trauma patients, penetrating, and neck; specific structures were also searched (larynx, trachea, esophagus, carotid artery, and jugular vein). Medline and EMBASE were searched from 1966 to 2007.

Articles were distributed among committee members for formal review. Each article was entered into a review data sheet that summarized the main conclusions of the study and identified any deficiencies in the study. Furthermore, reviewers classified each reference by the methodology established by the Agency for Health Care Policy and Research of the United States Department of Health and Human Services as follows: Class I—prospective, randomized, double-blinded study; Class II—prospective, randomized, nonblinded trial; or Class III—retrospective series, meta-analysis.

An evidentiary table (Table 1) was constructed using the 112 references that were identified: Class I, 1 reference; Class II, 30 references; and Class III, 81 references. Recommendations were made on the basis of the studies included in this table. Level I recommendations, usually based on Class I data, were meant to be convincingly justifiable on scientific evidence alone. Level II recommendations, usually supported by Class I and II data, were to be reasonably justifiable by available scientific evidence and strongly supported by expert opinion. Level III recommendations, usually based on Class II and III data, were to be made when adequate scientific evidence is lacking, but the recommendation is widely supported by available data and expert opinion.

RECOMMENDATIONS
Selective Workup—Operation Versus Selective Nonoperative Management
Recommendations

Level I: Selective operative management and mandatory exploration of penetrating injuries to zone II of the neck have equivalent diagnostic accuracy. Therefore, selective management is recommended to minimize unnecessary operations.

Level II: High resolution CT angiography offers appropriate diagnostic accuracy with minimal risk, making this the initial diagnostic study of choice when available.

Level III: No recommendations.

Scientific Foundation

Nonoperative management of penetrating neck wounds was common in the early 20th century. Based on a review of civilian experience, Fogelman and Stewart[5] recognized in 1956 that mandatory exploration led to less mortality than a strategy of observation. The rationale was that a significant number of seemingly asymptomatic patients with penetrating neck injuries actually have injuries.[6] In addition, negative neck explorations have little morbidity, though the financial cost is noteworthy; in 1981, Merion et al.[7] estimated the cost of a negative exploration at $1,930. Although an exploration under local anesthesia is appealing in terms of limiting recovery time and costs, Almskog et al.[8] found that neck explorations under local anesthesia, compared with general anesthesia, resulted in more hematomas and missed injuries. Consequently, mandatory exploration under general anesthesia for injuries that penetrate the platysma seemed reasonable.[9,10]

Mandatory exploration gained in popularity as studies showed that clinical symptoms were not present in 0% to 23% of the cases. However, mandatory exploration was negative 53% to 60% of the time and did not identify any injuries. In addition, some of the clinically silent injuries were venous and pharyngoesophageal injuries, which did not require operative therapy.[11–13]

Slowly, uncontrolled studies began to suggest that patients without clear signs of vascular or visceral injury could be observed,[14–34] though observation for up to 48 hours may be necessary,[35] depending on the use of ancillary tests. Jurkovich et al.[36] compared the results of mandatory exploration (the preference of the attending surgeon) in 47 patients with a selective approach in 53 patients using 43 angiograms and 14 endoscopies. In the mandatory exploration group, the negative exploration rate was 53%. In the selective approach group, 12 injuries were found but only five patients benefited from the work up. Some studies specifically recommended that to manage penetrating neck injuries, a well-staffed teaching hospital with a trauma service and immediate availability of radiologic and endoscopic evaluations is needed.[37] However, it has been shown that selective management can be safe in community hospitals with experienced surgeons.[38] Evidence of chest injury does not seem to be an indication for neck exploration.[39]

Debate on the issue of selective management continued as Meyer et al.[40] questioned this new approach of selective exploration for penetrating neck injuries. In a series of 113 patients, they obtained arteriograms, laryngotracheoscopy, esophagoscopy, and esophagography in each patient before a mandatory exploration. Forty-eight injuries were identified in 35 explorations. Of concern was the fact that five patients had six major injuries that were not identified by the preoperative testing. Thus they believed that a mandatory exploration approach was indicated.

More recent studies have consistently shown that the selective approach is a safe option. In a series of 128 asymptomatic patients who were observed by Biffl et al.,[41] based primarily on physical examination, only one patient had a missed injury (from an ice pick). Only 15% of these patients required adjuvant tests. Sriussadaporn et al.[42] also success-

Table 1 Penetrating Zone II Neck Trauma Evidentiary Table

No.	First Author	Year	Reference	Class	Conclusions
1	Bumpous JM	2000	Am J Otolaryngol 21:190–4	III	Zone II is the most common area of injury and most patients will require neck exploration. Major vascular injuries are evident with expanding hematoma, declining mental status, persistent bleeding from the wound or from the aerodigestive tract. Angiography is helpful if surgery is not immediately warranted. A significant number of patients will have long-term sequelae including hoarseness or dysphagia and they may require persistent tracheotomy.
2	Atta HM	1999	Am Surg 65:575–7	III	The Organ Injury Scale can be used to predict the length of hospital stay.
3	Bladergroen M	1989	Am J Surg 157:483–6	III	Aggressive resuscitation, evaluation, and operative intervention are needed for these patients.
4	Amirjamshidi A	2000	Surg Neurol 53:136–45	III	Early recognition of stigmas suggesting possible formation of extracranial traumatic vasculopathies such as aneurysms or arteriovenous fistulas should be highlighted for evaluation. Performing angiography promptly in suspected cases can pick up such traumatic vascular lesions earlier. Using simpler surgical techniques in situations in which more sophisticated endovascular equipment is unavailable can be life-saving.
5	Fogelman M	1956	Am J Surg 91:581–96	III	Mandatory exploration led to less mortality than a strategy of observation.
6	Markey JC	1975	Am Surg 41:77–83	III	They recommend exploring everyone with injury past the platysma as negative exploration has low morbidity.
7	Merion RM	1981	Arch Surg 116:691–6	III	Selective management is safe. Angiography and esophageal studies are needed.
8	Almskog BA	1985	Acta Chir Scand 151:419–23	III	They propose that all patients with wounds penetrating the platysma should be explored with general anesthesia. This is due to inadequate hemostasis (hematoma formation) and missed injuries when using local anesthesia.
9	Roon AJ	1979	J Trauma 19:391–7	II	All patients with platysma penetration should undergo operation since physical exam is insensitive and morbidity and mortality are low. Selective angiography can help in the planning of operations.
10	Walsh MS	1994	Injury 25:393–5	III	Policy of mandatory exploration is justified.
11	Saletta JD	1976	J Trauma 16:579–87	III	Policy of mandatory exploration is justified.
12	Elerding SC	1980	J Trauma 20:695–7	III	Selective management based on physical examination is appropriate.
13	Bishara RA	1986	Surgery 100:655–60	III	Mandatory exploration is safe and appropriate. Clinical evaluation preop not what is used for selective management.
14	May M	1975	Laryngoscope 85:57–75	III	Asymptomatic patients without hard or soft signs should not be explored. This study justifies selective rather than routine exploration.
15	Bostwick J, 3rd	1976	South Med J 69:550–3	III	The most common organ injury that is fatal is injury to the carotid. Morbidity is primarily related to neurological deterioration. Carotid injury repair should occur when there has been no preexisting neurological deficit. Reinstitution of cerebral flow to a previously acutely ischemic brain adds greater risk of intracerebral hemorrhage. Consideration to carotid ligation should be given in these situations. When the general condition of the patient permits, barium swallow is extremely reliable method for demonstrating esophageal perforation.
16	Blass DC	1978	J Trauma 18:2–7	III	Small, retrospective study. Decision to operate, or not, unclear.
17	Lundy LJ	1978	Surg Gynecol Obstet 147:845–8	III	Selective management is safe, but requires capability for appropriate diagnostic tests and close observation by nurses and house staff.
18	Meinke AH	1979	Am J Surg 138:314–9	III	This experience and a review of the literature support the concept of selective management of penetrating neck injuries with active observation.
19	Campbell FC	1980	Brit J Surg 67:582–6	II	A selective policy for surgical intervention is safe. A minimal morbidity and mortality can be obtained by adequate preoperative evaluation which includes the use of contrast radiography and angiography.
20	Pate JW	1980	Am Surg 46:38–43	III	Methodology not consistent with current standards of care. Careful and repeated physical examinations and observations supplemented by simple radiograph examinations allowed selection of a large group of patients who were satisfactorily treated by simple wound closure and clinical observations. Aggressive emergency room management and adequate exposure and repair of vascular injuries prevented cerebral damage so common in previous reports.

Table 1 Penetrating Zone II Neck Trauma Evidentiary Table (continued)

No.	First Author	Year	Reference	Class	Conclusions
21	Massac E	1983	Am J Surg 145:263–5	III	Our morbidity and mortality rates are slightly lower than those reported in most series. This review supports the concept that therapy for penetrating injuries to the neck should be individualized.
22	Shuck JM	1983	Ann Emerg Med 12:159–61	III	Selective management of neck injuries should be done.
23	Rao PM	1983	J Trauma 23:47–9	II	Recommend a policy of selective management
24	Demetriades D	1985	Ann R Coll Surg Engl 67: 71–4	III	Selective management is ok.
25	Cohen ES	1987	South Med J 80:26–8	III	Selective exploration of penetrating neck wounds is both safe and reasonable.
26	Ramadan HH	1987	Laryngoscope 97:975–7	III	A selective approach to penetrating neck wounds can be safe even in a prolonged military conflict.
27	Mansour MA	1991	Am J Surg 162:517–20	II	Selective neck exploration is efficacious and safe.
28	Roden DM	1993	Am Surg 59:750–3	III	The selective approach to the operative management of these patients is safe and effective in identifying those patients in need of operation and selecting out those patients who may be safely observed.
29	Luntz M	1993	Eur Arch Otorhinolaryngol 250:369–74	III	Patients with penetrating neck injuries should be differentiated into 2 basic categories: immediately life-threatening and not immediately life-threatening. Immediately life-threatening features include overt massive bleeding, expanding hematoma, non-expanding hematoma in the presence of hemodynamic instability, hemomediastinum, hemothorax. and hypovolemic shock, require In immediate surgical exploration. Those patients without immediately life-threatening injuries, but with any signs of vascular complication, signs of upper aerodigestive tract lesions, or peripheral neurological deficits, should undergo thorough imaging to determine the need for and nature of possible surgical intervention.
30	Sofianos C	1996	Surgery 120:785–8	II	Conservative management with selectively supplemented appropriate investigations is a viable proposition in this type of injury.
31	Klyachkin ML	1997	Am Surg 63:189–94	III	The data support the application of the selective management algorithm for zone II neck wounds. Preoperative ancillary diagnostic tests would have further reduced the negative exploration rate.
32	Hersman G	2001	Int Surg 86:82–9	III	More of a review of the change in practice from mandatory exploration to selective management. No conclusions can be drawn from their data.
33	Sheely CH	1975	J Trauma 15:895–900	III	Carefully selected patients can be observed for evolution of neck injuries with a resultant low morbidity and mortality.
34	Ayuyao AM	1985	Ann Surg 202:563–7	III	The frequency of operations for penetrating neck wounds without structural injuries was minimized in the selective exploration group.
35	Stroud WH	1980	Am J Surg 140:323–6	III	Mandatory exploration is not necessary, but if nonoperative management is pursued, exploration may be needed if any change in clinical course occurs. Observation for 48 h is recommended.
36	Jurkovich GJ	1985	J Trauma 25:819–22	III	In the absence of clinical signs of major vascular, esophageal, airway, or neurologic injury, the indication for ancillary diagnostic testing may best be defined by the anatomic location of the injury. Zone II injuries are rarely occult. Asymptomatic patients may safely be observed only. Zone I injuries should be aggressively evaluated by CXR, arteriography, and fluoroesophagography. Zone II injuries warrant arteriography. Aerodigestive tract studies of injuries to this neck zone are useless.
37	Ordog GJ	1985	J Trauma 25:238–46	III	A substantial number of patients with penetrating trauma to the neck can be selectively managed depending on the symptoms, signs, site and direction of trajectory, and whether the time between injury and entrance to the hospital is greater than 6 h. Patients who are stable and lack physical signs of obvious major neck injury can be evaluated by diagnostic radiologic and endoscopic techniques. If no significant injury is found, observation with repeated physical exams and 24 h availability of radiologic and endoscopic modalities must be adhered to.
38	Cabasares HV	1982	Am Surg 48:355–8	III	Selective management is safe. Prompt operation, when appropriate, can spare patients unnecessary and costly testing.
39	Goldberg PA	1991	Injury 22:7–8	II	Concomitant penetrating chest injury is not an indication for exploration of the neck.

Table 1 Penetrating Zone II Neck Trauma Evidentiary Table (continued)

No.	First Author	Year	Reference	Class	Conclusions
40	Meyer JP	1987	Arch Surg 122:592–7	III	Potentially lethal vascular and visceral structures in the neck may go undetected if selective exploration criteria are used in the decision to explore penetrating wounds to zone II of the neck.
41	Biffl WL	1997	Am J Surg 174:678–82	II	Selective management is safe and does not mandate diagnostic testing.
42	Sriussadaporn S	2001	Int Surg 86:90–3	III	Selective management based on clinical findings is safe.
43	Nason RW	2001	Can J Surg 44:122–6	III	Selective management may be appropriate, but the criteria for observation are unclear.
44	Narrod JA	1984	J Emerg Med 2:17–22	III	Mandatory exploration of penetrating anterior neck wounds is unnecessary and use of a selective approach to their evaluation is both safe and cost-effective. Observation does not mandate extensive ancillary diagnostic testing for level II and III injuries. For level I injuries, arteriography is performed and if the wound approaches the mediastinum, esophageal contrast studies and endoscopic evaluation are performed in selected patients. In this study, the sensitivity of esophagoscopy and esophageal contrast studies was less than 70%; therefore, injuries with abnormal soft tissue air undergo mandatory exploration despite the risk of negative exploration.
45	Narrod JA	1984	Arch Surg 119:574–8	II	Selective exploration for penetrating neck injuries is safe and cost-effective. Observation does not mandate extensive ancillary testing for level II and III injuries.
46	Velmahos GC	1994	Can J Surg 37:487–91	II	Large study of selective management, but 9% missed injuries seems high.
47	Golueke PJ	1984	J Trauma 24:1010–2	I	Mandatory and selective strategies are equivalent.
48	Atta HM	1998	Am J Surg 64:222–5	III	Transcervical injuries are more lethal than other types of injuries to the neck.
49	Hirshberg A	1994	Am J Surg 167:309–12	III	Transcervical penetration may be a predictor of major injury, supporting an approach of mandatory neck exploration.
50	Demetriades D	1996	J Trauma 40:758–60	II	This study does not support mandatory operation for all transcervical gunshot wounds. A careful clinical examination combined with the appropriate diagnostic investigations should determine the treatment modality. About 80% of these patients can safely be managed nonoperatively.
51	Gracias VH	2001	Arch Surg 136:1231–5	III	CT in stable selected patients with penetrating neck trauma seems safe. Invasive studies can often be eliminated when CT demonstrates trajectories remote from vital structures. Further prospective study of CT scan after penetrating neck trauma is needed.
52	Mazolewski PJ	2001	J Trauma 51:315–9	II	CT is good and can be used to eliminate the need for mandatory exploration.
53	Munera F	2004	Emerg Rad 10:303–9	III	CT angiography decreases the need for angiography.
54	Nunez DB, Jr	2004	Radiographics 24:1087–98	III	This is more of a review of the possible injuries that can be demonstrated with CT angiography. They point out that CT angiography may also provide valuable information regarding soft tissues, aerodigestive track, and spine.
55	Inaba K	2006	J Trauma 61:144–149	III	106 injuries. 15 needed urgent operation. 91 patients underwent CT angio. 100% sensitivity and 93.5% specificity in detecting all vascular and aerodigestive injuries sustained. Non-diagnostic studies were secondary to retained missile fragments.
56	Woo K	2005	Am Surg 71:754–758	II	Retrospective study of 130 patients. Patients who underwent CT angiogram had fewer explorations (3% vs. 33%) and fewer negative explorations (0% vs. 32%). Use of angiography and esophagography also decreased with use of CT angiography.
57	Bell RB	2007	J Oral Maxillofac Surg 65: 691–705	II	Retrospective study. 65 patients underwent CT angiography. The number of neck explorations decreased and virtually eliminated negative neck explorations.
58	Prgomet D	1996	Eur Arch Otorhinolaryngol 253:294–6	III	Wounds treated during the first 6 h after injury should be closed primarily but with obligatory drainage. Secondary closure is better for wounds treated more than 6 h after injury or in cases with larger tissue defects requiring larger local or free graft flaps for closure.
59	Danic D	1998	Mil Med 163:117–9	III	Primary closure of war wounds to the head and neck (supported by antibiotic therapy) and reconstruction of extensive laryngotracheal injuries with the medial layer of the cervical deep fascia were used for the first time as war surgery procedures.
60	Cooper A	1987	J Ped Surg 22:24–7	III	Selective management of neck injuries seems appropriate in children.

Table 1 Penetrating Zone II Neck Trauma Evidentiary Table (continued)

No.	First Author	Year	Reference	Class	Conclusions
61	Hall JR	1991	J Trauma 31:1614–7	III	Nonoperative observation of penetrating zone-II neck injuries is safe and the management of choice if active observation can be performed and the facilities for immediate operative intervention are available.
62	Thomas AN	1978	J Thorac Cardiovasc Surg 76:633–8	III	In stable patients, angiography helps avoid unnecessary operations and helped plan appropriate operations.
63	O'Donnell VA	1979	Am J Surg 138:309–13	III	Selective management based on angiography is safe and effective.
64	Smith RF	1974	Arch Surg 109:198–205	III	No firm conclusions regarding indications for angiographic evaluation can be drawn, but physical exam alone is unreliable.
65	Dunbar LL	1984	Am Surg 50:198–204	III	Selective management is safe when esophagrams and angiograms are included.
66	Hiatt JR	1984	J Vasc Surg 1:860–6	III	Negative angiogram allows safe nonoperative management.
67	North CM	1986	Am J Roentgenol 147:995–9	II	Vascular injury incidence was 30% when there was an absent pulse, bruit, hematoma or alteration of neurologic status. Patients were unlikely to have clinically significant vascular trauma if the above signs were missing. Higher rate (50%) of vascular injury with trauma above the angle of the mandible. Gunshot wounds cause vascular injury more frequently than stab wounds.
68	Hartling RP	1989	Radiology 172:79–82	III	Occult vascular trauma is unlikely in patients with minor physical findings. Angiography is indicated in zone II and III injuries associated with major physical findings, but not in those with minor physical findings.
69	Rivers SP	1988	J Vasc Surg 8:112–6	III	Arteriography for penetrating neck trauma is usually unnecessary for observation of patients in stable condition without suggestive physical findings. Thorough neck exploration with dissection of the carotid sheath in patients with physical examination criteria for surgery eliminates the need for angiography in most cases and avoids the consequences of a possible false-negative study.
70	Noyes LD	1986	Ann Surg 204:21–31	III	Compared to mandatory exploration, angiography with panendoscopy is an equally safe and acceptable method of initial exploration for stable patients with penetrating neck wounds.
71	Sclafani SJ	1991	J Trauma 31:557–62	III	Physical examination is insufficient. Angiography or exploration is indicated if platysma is violated.
72	Menawat SS	1992	J Vasc Surg 16:397–400	III	Location and physical examination can rule out a major arterial injury necessitating operation.
73	Nemzek WR	1996	Am J Neurorad 17:161–7	III	Prevertebral soft tissue swelling and bullet fragmentation in proximity to a vessel are non-specific findings and are present in many patients with negative angio. No comment on computed tomography.
74	Jarvik JG	1995	Am J Neuroradiol 16:647–54	II	Clinical exam is good and not doing angiograms saves 3.08 million dollars per central nervous system event prevented.
75	Demetriades D	1995	Arch Surg 130:971–5	II	Doppler and physical exam have 100% sensitivity for clinically important lesions in the vasculature of the neck.
76	Demetriades D	1997	World J Surg 21:41–7	II	Physical examination is sufficient to identify patients who require arterial or esophageal evaluation. Duplex is a reasonable alternative to angiography.
77	Bynoe RP	1991	J Vasc Surg 14:346–52	II	Ultasound is accurate and cost-effective.
78	Montalvo BM	1996	Am J Neuroradiol 17:943–51	II	Color Doppler sonography is as accurate as angiography in screening clinically stable patients with zone II or II injuries and no signs of active bleeding.
79	Ginzburg E	1996	Arch Surg 131:691–3	II	Duplex ultrasound is a reliable method for identifying vascular trauma in the stable patient. Abnormal ultrasound results should warrant subsequent angiography.
80	Corr P	1999	S Afr Med J 89:644–6	II	Duplex is a reasonable screening test for penetrating arterial injuries.
81	Munera F	2000	Radiology 216:356–62	II	The sensitivity and specificity of helical CT angiography are high for detection of major carotid and vertebral arterial injuries resulting from penetrating trauma. The entire neck must be included in the examination.

Table 1 Penetrating Zone II Neck Trauma Evidentiary Table (continued)

No.	First Author	Year	Reference	Class	Conclusions
82	Munera F	2002	Radiology 224:366–72	III	Helical CT angiography can be reliably used to evaluate penetrating neck trauma in the stable patient. Patients with bruits or thrill at admission may be better managed by conventional angiography because of the likelihood of endovascular therapy. Helical CT angiography is limited by artifact due to metal which may obscure arterial segments; therefore, these patients should undergo conventional angiography. Subtle lesions such as intimal flaps may be missed by helical CT angiography therefore underestimating the total number of injuries.
83	Ofer A	2001	Eur J Vasc Endovasc Surg 21:401–7	III	CT angiography was 100% accurate for carotid artery injuries in 12 patients with penetrating trauma and 4 with blunt trauma. One blunt and 1 penetrating injury detected.
84	Splener CW	1976	Arch Surg 111:663–7	III	Early signs were subtle. Small amounts of mediastinal and cervical air tended to be overlooked or erroneously attributed to other causes, such as associated pneumothorax. Once suspected, the possibility of esophageal disruption was not always pursued with optimum vigor.
85	Asensio JA	1997	J Trauma 43:319–24	III	Esophageal injuries carry a high morbidity and mortality. Though the sample size is small, there does appear to be an increased morbidity associated with the diagnostic workup and its inherent delay in operative repair of these injuries. For centers practicing selective management, rapid diagnosis and definitive repair should be made a high priority.
86	Asensio JA	2001	J Trauma 50:289–96	II	Preoperative evaluation for esophageal injuries should be carried out expeditiously to avoid delays that are detrimental to the patient.
87	Hatzitheofilou C	1993	Br J Surg 80:1147–9	III	Diagnose and repair esophageal injuries early (<24 h).
88	Symbas PN	1980	Ann Surg 191:703–7	III	Perform EGD in patients with missile trajectory near the esophagus irrespective of physical signs of esophageal injury. Repair all injuries with plication in addition to primary repair.
89	Cheadle J	1982	Surg Gynecol Obstet 155: 380–4	III	Repair esophageal injuries.
90	Shama DM	1984	Br J Surg 71:534–6	III	Tracheal wounds are usually recognized early but cervical esophageal injuries are not. Early recognition & referral are associated with low morbidity & mortality. Late recognition & referral carry a high morbidity and mortality rate.
91	Popovsky J	1984	J Trauma 24:337–9	III	Due to extensive tissue damage in GSWs, primary repairs of thoracic esophageal perforations have a high incidence of failure. Defunctionalization of the esophagus through ligation of the distal esophagus, gastrostomy, and cervical esophagostomy provides a safer method. Use of a double strand of absorbable Dexon to ligate the distal esophagus makes a second thoracotomy unnecessary for ligature removal. Routine use of hyperalimentation avoids the need for feeding jejunostomy. All patients with cervical esophageal lesions are routinely explored through a pre-sternocleidomastoid incision on the side of the injury and the perforation closed with 2 layers of nonabsorbable monofilament and drained.
92	Armstrong WB	1994	Ann Otol Rhinol Laryngol 103:863–71	III	Treat as pharyngeal injuries and repair primarily. Diversion leads to complications such as strictures.
93	Stanley RB	1997	J Trauma 42:675–9	III	Injuries located in the upper portion of the hypopharynx can be routinely managed without surgical intervention. Neck exploration and adequate drainage of the deep neck spaces are, however, mandatory for all penetrating injuries into the cervical esophagus and most injuries into the lower portion of the hypopharynx.
94	Madiba TE	2003	Ann R Coll Surg Engl 85: 162–6	II	Non-operative management of penetrating injuries to the cervical esophagus is safe and effective.
95	Minard G	1992	Am Surg 58:181–7	III	Laryngotracheal trauma usually presents with symptoms and/or signs, but they may be minimal and nonspecific. Emergency tracheostomy should not be delayed if ventilation is compromised. Concomitant esophageal injuries are frequent and predispose the patient to postoperative complications. Airway compromise frequently correlates with severity of injury and risk for complications.

Table 1 Penetrating Zone II Neck Trauma Evidentiary Table (continued)

No.	First Author	Year	Reference	Class	Conclusions
96	Grewal H	1995	Head Neck 17:494–502	III	Endotracheal intubation can be accomplished safely in selected patients with penetrating laryngotracheal injuries. Digestive tract injuries can often be clinically occult & early evaluation of the esophagus is vital. In patients with minor injuries, tracheostomy does not appear to be mandatory.
97	Weigelt JA	1987	Am J Surg 154:619–22	III	For selective management, arteriography, esophagography and rigid esophagoscopy (if esophagram is equivocal) are necessary to rule out injuries that require exploration.
98	Wood J	1989	J Trauma 29:602–5	III	Unstable patients require immediate exploration. Stable patients with equivocal physical findings can be managed according to results of esophageal examination and angiography. Patients with low probability of injury due to location and clinical presentation can be observed. Regardless of method of management, those with a possibility of esophageal injury should undergo esophagram and/or esophagoscopy.
99	Ngakane H	1990	Br J Surg 77:908–10	III	Tracheal injury in the absence of life-threatening airway problems can be treated successfully with a conservative approach. Patients with minimal symptoms of visceral injury following penetrating cervical trauma may be selected for further evaluation based on the simple water swallowing test. A severe pain response on swallowing should elicit a contrast swallow. Patients with a normal study and those with minimal leakage of contrast material can be managed non-operatively having a repeat exam on day 5.
100	Srinivasan R	2000	Am J Gastroenterol 95:1725–9	III	Endoscopy is a safe and reliable method for evaluating the esophagus for penetrating trauma.
101	McCormick TM	1979	J Trauma 19:384–7	II	Physical examintaion is unreliable in ruling in or out vascular trauma, although no subcategorization of neck and extremity injuries was done, nor was there a description of how serious the missed injuries were.
102	Metzdorff MT	1984	Am J Surg 147:646–9	III	Clinical findings are a reliable indicator of significant trauma.
103	Apffelstaedt JP	1994	World J Surg 18:917–9	III	Physical examination does not help determine which patients have life-threatening injuries. Mandatory exploration is recommended.
104	Demetriades D	1993	Br J Surg 80:1534–6	II	Physical examination is reliable in detecting significant injuries in penetrating neck trauma.
105	Gerst PH	1990	Am Surg 56:553–5	II	Selective management, when guided by repeated, careful examinations, is safe and avoids unnecessary operations.
106	Beitsch P	1994	Arch Surg 129:577–81	III	Neither mandatory neck exploration nor mandatory arteriography is necessary. Physical examination should be used to assess for possibility of injury in penetrating neck trauma.
107	Atteberry LR	1994	J Am Coll Surg 179:657–62	II	Vascular injury can be excluded by physical exam.
108	Sekharan J	2000	J Vasc Surg 32:483–9	II	Patients with Zone II penetrating neck wounds can be safely and accurately evaluated by physical examination alone. The missed injury rate is 0.7% (1 of 145), which is comparable to angiography in accuracy, but less costly and non-invasive.
109	Azuaje RE	2003	Am Surg 69:804–7	III	Routine angiography may be unnecessary for patients with penetrating neck injuries and a negative physical exam.
110	Mohammed GS	2004	Euro J Vasc Endovasc Surg 28:425–30	II	Prospective study of stable patients with gunshot wounds to the neck. All underwent physical exam (one examination, not serial) and angiography by protocol. 10 patients without signs of vascular injury had a vascular injury, but the nature of these injuries was not described.
111	Goudy SL	2002	Laryngoscope 112:791–5	III	Blunt trauma can result in perforation of the aerodigestive tract. Some stable patients with evidence of upper aerodigestive tract injury can be managed without surgery, but a high index of suspicion for airway compromise and associated facial injuries must be considered. Flexible and direct laryngoscopy and esophagoscopy are highly recommended. Most of the lacerations identified are 1 to 2 cm in diameter. Contrary to previous studies, patients with these injuries can be managed successfully without surgical exploration. Each patient must be closely followed and elective neck exploration undertaken when sepsis is suspected or a vascular injury is evident.
112	Gonzalez RP	2003	J Trauma 54:61–4	II	CT scan does not appear to contribute to the diagnostic sensitivity of physical examination for the diagnosis of surgically significant airway or arterial injury. CT does improve the diagnostic sensitivity of physical exam for venous injury.

fully observed 17 asymptomatic patients. Only 2 of 40 patients who underwent exploration did not need the operation, though they seemed to have deep wounds. In asymptomatic patients, Nason et al.[43] found that 67% underwent negative explorations. All zone II vascular injuries were symptomatic. Narrod and Moore[44,45] reviewed their 10-year experience with penetrating neck trauma. In the first 6 years, mandatory exploration led to a 56% rate of negative explorations. In the next 4 years, a selective management strategy was used. Forty-one of 48 patients who underwent exploration had significant injuries,[45] whereas 29 asymptomatic patients were observed without any missed injuries. Few ancillary studies were performed in this group. In a large, retrospective study from Johannesburg, South Africa, Velmahos et al.[46] compared results with patients who underwent immediate surgical exploration versus constant monitoring. In the exploration group, 3% of the explorations were unnecessary; mortality was 4.2%. In the monitoring group, 9% had missed injuries; mortality was 4%. Criteria for observation versus exploration were not clear making the interpretation of the 9% missed injury rate difficult. The only randomized trial comparing mandatory neck exploration with a selective approach based on physical examination and radiographs was performed by Golueke et al.[47] in 160 patients. There was no difference in hospital stay, morbidity, or mortality.

Management of transcervical gunshot wounds deserves separate consideration because of the high likelihood of major injury.[48] Hirshberg et al.[49] explored 41 patients with transcervical gunshot wounds. Twenty-eight had more than one zone of the neck involved. Although seven patients did not have major injuries, 34 patients had 52 major injuries to cervical structures mainly involving vessels and the upper airway. Sixteen presented with life-threatening problems. They recommended mandatory exploration. In contrast, Demetriades et al.[50] found that a selective approach based on physical examination, angiography, esophagoscopy, and esophagography was safe.

Helical CT angiography is the newest technology to be tested for identifying vascular injuries from penetrating neck trauma, particularly arterial injuries. Because it might also be useful for identifying or ruling out other injuries (e.g., aerodigestive tract injury), this modality is particularly intriguing as a "one stop shop" to evaluate asymptomatic patients for selective operative management. The speed and resolution of this modality continues to improve. Gracias et al.[51] have already recommended that if a CT demonstrates trajectories that are remote from vital structures, the need for additional invasive studies can be eliminated.

In the setting of a mandatory exploration protocol, Mazolewski et al.[52] found that CT angiography, compared with operative findings, was 100% sensitive and 91% specific in 14 patients. Both Munera et al.[53] and Nunez et al.[54] pointed out the utility of CT angiography for identifying nonvascular soft tissue injuries, and the vascular injuries. Inaba et al.[55] reviewed their experience with 106 patients who had pene-

trating injuries to the neck. Fifteen required urgent operation. The remainder underwent CT angiogram. Two tracheal injuries and two carotid artery injuries were identified. No injuries requiring intervention were missed. Use of CT angiography can safely decrease the number of neck explorations and, more importantly, the number of negative neck explorations.[56,57] In addition, CT angiography can decrease, though not eliminate, the need for formal angiography and esophagography in some patients.[56]

Management of neck wounds in the military setting may be different from that in the civilian world. Prgomet et al.[58] found that injuries that did not penetrate the platysma did not cause significant injuries. Forty-nine of 84 patients who underwent immediate exploration had injuries to vital structures. They also found that it was safe to close the wound primarily if it was seen within 6 hours of injury. In their experience, even extensive laryngotracheal injuries could be repaired safely.[59]

There is little data on selective management of penetrating neck injuries in children. Small studies[60,61] suggest that a selective management strategy is safe.

Diagnosis of Arterial Injury

Recommendations

Level I: No recommendations.

Level II: CT angiography or duplex US can be used in lieu of arteriography to rule out an arterial injury in penetrating injuries to zone II of the neck.

Level III: CT of the neck (even without CT angiography) can be used to rule out a significant vascular injury if it demonstrates that the trajectory of the penetrating object is remote from vital structures. With injuries in proximity to vascular structures, minor vascular injuries such as intimal flaps may be missed.

Scientific Foundation

In the era of mandatory neck exploration for penetrating trauma, there seemed to be little need for angiography, though some[9] suggested that the angiogram could assist in operative planning and thereby minimize morbidity or rule out the need for exploration.[62,63] Physical examination, however, seemed unreliable for ruling out arterial injury.[64] Delayed pseudoaneuryms and neurologic events have been described in originally asymptomatic patients, prompting some to advocate angiography in all such patients.[65] A negative arteriogram in a stable patient can rule out an arterial injury.[66] North et al.[67] reviewed the records of 139 stable patients with penetrating neck trauma. Patients who had at least soft signs of vascular injury (absent pulse, bruit, hematoma, or altered neurologic status) had a 30% incidence of vascular injury by angiography, whereas only 2 of 78 asymptomatic patients had injuries (one minor and one that did not affect management). Gunshot wounds were more likely than stab wounds to cause vascular injury. Similarly, Hartling et al.[68] found, using angiography, that 43 patients with stab wounds to the neck and

minimal symptoms had no significant injuries. Even in the 18 patients with physical findings consistent with a vascular injury, only two had significant injuries. Similarly, Rivers et al.[69] questioned the value of angiography. Of 63 angiograms in 61 patients, only 6 were abnormal. Three were thought to be spurious on subsequent review, two were clinically insignificant, and one required surgery. No significant arterial injuries were identified by arteriography in the absence of suggestive physical findings. No major arterial injuries that were missed preoperatively were discovered during exploration. Angiograms did not alter the course of management. Noyes et al.[70] examined the accuracy of a selective management strategy. Arteriography and laryngoscopy/bronchoscopy were 100% accurate.

In contrast, Sclafani et al.[71] found that 10 of 26 patients who had positive angiograms for penetrating vascular injury to the neck had undergone the angiogram solely because of proximity. Physical examination had a sensitivity of 61% and specificity of 80%. They also found no differences in their results based on mechanism of injury. They suggested that proximity should not be abandoned as an indication for angiography in these patients.

Menawat et al.[72] performed angiography for proximity or soft signs of vascular injury. Fifteen injuries were found on 45 angiograms. Forty-two patients without any signs of injury were successfully observed without angiography or operation. Overall, only one patient had a significant injury that was not predicted by physical examination.

In contrast, Nemzek et al.[73] found that proximity, based on the addition of plain films or CT of the neck showing prevertebral soft-tissue swelling, missile fragmentation, or missiles adjacent to major vessels can be useful, but are nonspecific radiographic signs.

To examine the cost effectiveness of angiography, Jarvik et al.[74] studied 111 patients with penetrating neck trauma. Forty-five of the 48 patients with vascular injuries had abnormal clinical findings. Management in the other three patients was not altered by the angiogram. They calculated the cost of screening angiography in asymptomatic patients to be approximately $3.08 million per central nervous system event.

Demetriades et al.[75] prospectively compared physical examination and duplex US imaging with angiography in 82 stable patients with penetrating neck injuries. Only 11 patients had vascular injuries by angiography; and only two of these injuries needed to be repaired. The serious injuries were detected or suspected on physical examination, but six lesions that did not require treatment were missed (sensitivity 100% for serious injuries, but 45% for all injuries). By duplex US imaging, 10 of 11 injuries, including all serious ones, were identified, for an overall sensitivity of 91% (100% for clinically important lesions) and specificity of 99%. Further studies by Demetriades et al.[76] included 223 patients. Of the 160 asymptomatic patients, 11 had injuries that did not require treatment. Overall, duplex US was 92% sensitive (100% for

findings that required an operation) and 100% specific for defining an injury. Similarly, Bynoe et al.[77] found that duplex US was 95% sensitive and 99% specific for vascular injuries after both neck and extremity trauma. The only missed injuries were two shotgun pellet injuries that did not need repair.

In a prospective, double-blind study, Montalvo et al.[78] found that US identified all 10 significant injuries in 52 patients with penetrating neck trauma. Duplex US did not identify reversible carotid narrowing in one patient and did not visualize two vertebral arteries. Another report by the same group[79] found in 55 patients that duplex US had 100% sensitivity and 85% specificity.

Corr et al.[80] reported that duplex US picked up two intimal flaps that were not identified on angiography.

Munera et al.[81] prospectively studied 60 patients, who had 10 vascular injuries. There was one missed injury by CT angiography because the study actually did not include the entire neck. They later[82] suggested that patients with bruits or thrills at admission may be better treated by undergoing conventional angiography because of the potential for endovascular therapy. Helical CT angiography is limited by artifact due to metal, which may obscure arterial segments; therefore, these patients should undergo conventional angiography.

Ofer et al.[83] reviewed their experience with CT angiography in 16 patients (12 with penetrating trauma and four with blunt) and found no missed injuries, although only one patient with penetrating trauma had a carotid injury (confirmed at operation).

Diagnosis of Esophageal Injury

Recommendations

Level I: No recommendations.

Level II: Either contrast esophagography or esophagoscopy can be used to rule out an esophageal perforation that requires operative repair. Diagnostic workup should be expeditious because morbidity increases if repair is delayed by more than 24 hours.

Level III: No recommendations.

Scientific Foundation

The problem with penetrating injuries to the esophagus is that there are frequently no findings on physical examination. Esophagography can miss the injury.[84] This is of grave concern since late referral and management can lead to significant morbidity and mortality.[85–87] Early diagnosis and management, often with primary repair, lead to good outcomes.[88–90] Even gunshot wounds can be closed primarily[91]; more complex repairs may lead to strictures.[92] Location of the injury can affect outcome as injuries above the arytenoid cartilages can be managed without intervention, whereas more inferior injuries require neck drainage to prevent a deep tissue infection.[93] Madiba et al.[94] also found that patients with small injuries and contained perforation on contrast studies could be observed without operation unless there was another indication

for exploration. All 26 patients with injuries had odynophagia. Of 17 patients managed nonoperatively, only one developed local sepsis. Six patients had associated tracheal injuries. In addition, patients with tracheal injuries have worse outcomes if they have concomitant esophageal injuries.[95,96]

Noyes et al.[70] found that esophagograms were 90% accurate and esophagoscopy was 86% accurate. Weigelt et al.[97] used a strategy of esophagography followed by rigid esophagoscopy if the esophagogram were equivocal to identify esophageal injuries in patients who had no or minimal symptoms after penetrating neck trauma. All 10 injuries in 118 patients were identified. Wood et al.[98] found that esophagography alone was 100% sensitive and 96% specific in 225 patients. Ngakane et al.[99] reviewed 109 patients with penetrating neck trauma. All patients with gunshot wounds underwent esophagography, whereas patients with stab wounds were only studied if they had pain with swallowing. Twenty-nine studies were performed and four injuries were identified. All were observed without intervention. Repeat contrast studies demonstrated resolution of the injury.

In 23 patients with esophageal injuries, Armstrong et al.[92] found that esophagography only identified 62% of the injuries whereas rigid esophagoscopy detected all injuries. Srinivasan et al.[100] found reasonable accuracy with flexible endoscopy. In 55 patients, flexible endoscopy identified the only two injuries, but suggested an injury in four patients, resulting in four negative explorations, for an overall sensitivity of 100% and specificity of 92%.

Value of the Physical Examination

Recommendations

Level I: No recommendations.

Level II: No recommendations.

Level III: Careful physical examination using protocols for serial examinations, including auscultation of the carotid arteries, is >95% sensitive for detecting arterial and aerodigestive tract injuries that require repair. Given the potential morbidity of missed injuries, clinicians should have a low threshold for obtaining imaging studies.

Scientific Foundation

Early reports suggested that the physical examination is unreliable to rule out a vascular injury. McCormick and Burch[101] found physical examination of neck and extremity injuries yielded a 20% false negative rate and a 42% false positive rate. Metzdorff and Lowe[102] found an overall 80% accuracy of physical examination. Apffelstaedt and Muller[103] found that clinical signs were absent in 30% of patients with positive neck explorations and in 58% of patients with negative neck explorations, supporting their approach of mandatory exploration.

More recently, Demetriades et al.[104] studied 335 patients with penetrating neck injuries. Sixty patients underwent exploration for positive physical examination findings or a positive workup, whereas 269 asymptomatic patients were observed. Only two of the latter patients later required elective procedures. In a subsequent article, this group demonstrated that physical examination did not miss any major vascular or esophageal injuries that required intervention; though minor injuries were identified by angiography (1 of 8 required intervention) and esophagography. Using a selective approach based on careful and repeated physical examinations, Gerst et al.[105] observed 58 asymptomatic patients without sequelae. Of the 52 patients who underwent prompt exploration based on physical examination, 17% did not have significant injuries. Similarly, Beitsch et al.[106] found that only 1 of 71 asymptomatic patients had a vascular injury detected by angiography. Thus, in this patient population physical examination ruled out 99% of vascular injuries and the yield for angiography was 1.4%. Atteberry et al.[107] found that if patients did not have physical examination findings of arterial injury (active bleeding, expanding hematoma or hematoma larger than 10 cm, a bruit or thrill, or a neurologic deficit), no vascular injuries were present based on angiography, duplex ultrasound, or clinical follow-up. They observed patients for at least 23 hours.

Conversely, Sekharan et al.[108] found that only 2 of 30 patients who underwent exploration for hard signs of vascular injury did not have a significant injury. Twenty-three of 114 asymptomatic patients underwent angiography for proximity or involvement of another zone. Only one of these patients needed an operation. All 91 other patients with negative physical examinations were safely observed without imaging. Azuaje et al.[109] found that 68% of patients with positive physical examination had a positive angiogram. Of the 89 patients with negative physical examinations, only three had positive angiograms, but none needed operations. Overall, physical examinations had sensitivity of 93% and a negative predictive value of 97%. Both sensitivity and negative predictive value for injuries requiring operation were 100%.

A recent study by Mohammed et al.[110] suggests caution in relying on physical examination alone to rule out vascular injuries secondary to gunshot wounds of the neck. Of 59 patients with gunshot wounds to any zone of the neck, 13 had positive physical findings suggesting a vascular injury, whereas 10 patients with negative physical findings were found to have injuries by angiography, giving physical examination a negative predictive value of 67%. The significance of these findings is difficult to determine, because they included all zones of the neck and did not define the severity of the injuries that were identified.

Subcutaneous emphysema or crepitance are physical findings suggestive of aerodigestive tract injuries that may require operative intervention. Goudy et al.[111] reviewed the cases of 19 patients with emphysema or crepitance. Twenty-one percent had dysphagia, and 63% had stridor or hoarseness. Most underwent direct laryngoscopy and esophagoscopy. Patients without demonstrable injuries or small tears were successfully observed without exploration.

The best study, though small, that attempted to determine whether imaging adds to physical examination in the evaluation of patients with penetrating neck injuries was that by Gonzalez et al.[112] Forty-two patients, who did not have obvious need for operation at admission, underwent soft tissue dynamic CT of the neck and esophagography before mandatory exploration. All tracheal and carotid injuries were identified by physical examination. Two of four esophageal injuries (both from stab wounds) were missed by both CT and esophagography. CT was better than physical examination for identifying venous injuries, but most of these did not require intervention.

FUTURE DIRECTIONS

Selective management of penetrating injuries to zone II of the neck has become common for asymptomatic patients. The roles of physical examination, arteriography, duplex US, CT angiography, esophagography, and esophogoscopy remain unclear. At the moment, the single imaging modality that holds the greatest potential for ruling out vascular, tracheal, and esophageal injuries is CT angiography. Additional trials are needed to confirm this hypothesis. As the resolution of CT images improves, accuracy will surely increase. Rapid definitive imaging studies may allow early discharge of patients with neck injuries.

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