Panendoscopy with Arteriography Versus Mandatory Exploration of Penetrating Wounds of the Neck

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Of 193 patients with penetrating wounds of the neck, 76 had only surgical exploration; 57 had only nonsurgical exploration including one or more of the following: arteriography, bronchoscopy, laryngoscopy, esophagoscopy, and contrast-swallow esophagogram; and 60 had both surgical and nonsurgical exploration. Eighty-six patients were wounded by gunshot, 108 by stabbing. Presenting signs and symptoms were an unreliable method of predicting presence or absence of injury. Overall negative rate of surgical exploration was 50% (54% of the stabblings and 45% of the gunshots). Accuracy of nonsurgical exploration was assessed by comparing to surgery. Arteriography was 100% accurate, a combination of bronchoscopy and laryngoscopy was 100% accurate, contrast-swallow esophagogram was 90% accurate, and esophagoscopy was 86% accurate. The literature was reviewed regarding the accuracy of nonsurgical as well as surgical exploration. The one complication attributed to nonsurgical exploration was a symptomatic anemia, while there were two wound infections resulting in increased length of stay associated with negative surgical exploration. Overall mortality rate was 5.6%. The average length of stay for nonsurgical exploration only was 2.8 days, for negative surgical exploration was 4.2 days, and for positive surgical exploration was 9.5 days. Financial cost of a negative surgical exploration was $3185, while for four-vessel cerebral arteriography with panendoscopy it was $3492. More studies need to be done, particularly concerning venography and esophagoscopy. However, considering the fact that surgical exploration should by no means be considered 100% accurate, the data in this study support the fact that arteriography with panendoscopy represents an equally safe and acceptable method of exploration of penetrating wounds of the neck for stable patients without specific signs and symptoms of injury and can be expected to result in a reduced number of negative surgical explorations and their associated morbidity as well as a reduced length of hospital stay, although at a slightly higher financial cost when compared to mandatory surgical exploration.

Proper evaluation and management of penetrating wounds to the neck remain a controversial subject, with opinion in the literature evenly divided. Many authors advocate routine surgical exploration of all injuries that penetrate the platysma, citing the high morbidity and mortality associated with missed injuries and the inadequacy of presenting signs and symptoms as an indication of injury. In return, they accept a rather high rate of negative surgical exploration with its accompanying low, but not insignificant, morbidity. Other authors advocate passive observation of carefully selected patients based on the absence of specific signs and symptoms of injury or in the presence of negative findings on contrast-swallow esophagogram or arteriography, citing no increase in mortality or morbidity as well as a reduced rate of negative surgical exploration. Some authors have also included esophagoscopy in the nonsurgical workup. With respect to the literature, no authors have thoroughly evaluated the use of a complete nonsurgical exploration using a combination of arteriography, laryngoscopy, bronchoscopy, and esophagoscopy.

As an alternative to mandatory surgical exploration, the question arises whether patients who are stable and without obvious clinical signs of injury can instead be initially evaluated, not by passive observation but by an active though nonsurgical exploration utilizing arteriography and panendoscopy (laryngoscopy, bronchoscopy, and esophagoscopy) to assess vascular and visceral injury, undergoing surgery only in the presence of positive findings on nonsurgical exploration or upon acute deterioration in course. If this is indeed a valid method of evaluation and not associated with any increase in mortality, morbidity, or false-negative findings, it could become a more desirable form of management. It seems reasonable to assume that selective nonsurgical evaluation would result in a reduced rate of negative surgical exploration as

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well as a reduced rate of morbidity associated with those negative explorations. The potential also exists for reducing the length of hospital stay and possibly the financial cost to the patient as well.

Methods

A total of 294 patients with a diagnosis of penetrating wound of the neck by the International Classification of Diseases were discharged from or died at the Charity Hospital of New Orleans during the 5-year period from January 1, 1980 through December 31, 1984. Of these, 74 patients were excluded from the study because of one or more of the following reasons: their wound was superficial only and was sutured primarily in the accident room; the wound was due to blunt trauma; or, upon closer chart examination, the wound was found to be miscoded and either in the face, head, chest, or back, not to the neck. Additionally, seven charts were lost or otherwise unobtainable at the time of study.

Of the 213 patients remaining in the study, the median age was 29, with a range of 2 to 62 years. There were 179 males and 34 females; 154 were black and 59 were white. Eighty-six of the wounds were caused by gunshot, 108 by knife or other sharp instrument, ten by shotgun, four by pellet or BB, and five by motor vehicle accident. One hundred thirty-four were single wounds to the neck, while 79 were multiple wounds involving other areas of the body as well. Ninety-five patients had wounds to the anterior neck, 48 to the left lateral, 41 to the right lateral, and 29 to the posterior.

Of these 213 patients, any patients who were either not stable or exhibited signs and symptoms of vascular or visceral injury such as shock, large amount of blood lost, deteriorating course, obvious arterial bleed, expanding hematoma, absent or diminished pulse, bruit, hemoptysis, air blowing from wound, hemotorax, hematemesis, or neurological findings were taken immediately to the operating room after appropriate resuscitation for formal neck exploration and repair of any injuries, unless the supervising surgeon determined that it was safe to explore them nonsurgically. Those stable patients without such signs and symptoms were divided into two groups. In one group, patients underwent immediate surgical exploration, while in the other patients were evaluated by nonsurgical exploration including a combination of one or more of the following: arteriography, venography, laryngoscopy, bronchoscopy, esophagoscopy, and contrast-swallow esophagogram. These patients then underwent surgery only in the presence of positive findings on nonsurgical exploration or upon acute hemodynamic or respiratory deterioration. The decision as to surgical or nonsurgical exploration lay with the primary surgeon.

Results

Of the 213 patients in the study, 17 were essentially dead on arrival or died in the accident room with no procedures performed other than unsuccessful resuscitative measures. An additional three patients died anywhere from 4 to 46 days postadmission from high spinal cord transection with no procedures performed or indicated because of the nature of their injuries. Of the remaining patients, 76 had only surgical exploration, 57 had only one or more forms of nonsurgical exploration, while 60 had both surgical as well as some form of nonsurgical exploration. Included in these 60 patients were 19 patients who were operated on as a result of positive or nonconclusive findings on previous nonsurgical exploration and 41 patients who had nonsurgical exploration in conjunction with their surgery. Alternately combining these three subgroups of patients yielded 136 patients who underwent surgical exploration whether or not they also underwent nonsurgical exploration, and 117 patients who underwent some form of nonsurgical exploration whether or not they also underwent surgical exploration (Fig. 1).

Presenting Signs and Symptoms

The presenting signs and symptoms of the surgical as well as nonsurgical patients are listed in Table 1. As was to be expected, the nonspecific signs such as shock or crepitance occurred often, but it is noteworthy that shock (defined as a systolic blood pressure less than 70 mmHg) was present in eight of the patients with negative surgical explorations as well as in 18 of those with positive explorations, while crepitance or subcutaneous air was found in seven of the patients with negative surgical explorations as well as in 18 of those with positive explorations. On the other hand, specific signs such as hematemesis or air blowing from the wound were found only in patients with positive surgical explorations but occurred in only a small total number of patients, eight and five, respectively. Also of note is that several signs normally considered rather specific were found in patients who subsequently had negative surgical or nonsurgical examinations; one patient noted on admission as having a bruit suggestive of a carotid artery venous fistula was later found to have an unrecognized heart murmur and atherosclerotic disease, while two patients noted as having hemoptysis suggestive of tracheal or laryngeal injury were each found to be bleeding from a lung parenchymal injury from a second gunshot wound to the chest.

Those patients who had negative nonsurgical explorations had approximately the same number of signs and symptoms suggestive of serious injury as the patients who had negative surgical explorations; of 57 patients with
74 patients excluded (see text) → Total of 294 patients identified → 7 charts unavailable for study

213 patients available for study → 20 patients essentially DOA or considered unsalvageable

76 patients underwent surgical exploration only → 60 patients underwent both surgical and nonsurgical exploration*

7 Deaths
2 from hemorrhagic shock
2 from MI 2* hemorrhagic shock
1 from brain contusion
1 from anoxic brain damage
1 from hemorrhagic infarction 2° reanastomosed carotid artery.

7 Deaths
1 from ischemic infarction secondary to carotid artery laceration

136 patients underwent surgical exploration whether or not they also had nonsurgical exploration

117 patients underwent nonsurgical exploration whether or not they also had surgical exploration

213 patients available for study → 20 patients essentially DOA or considered unsalvageable

76 patients underwent surgical exploration only

7 Deaths
2 from hemorrhagic shock
2 from MI 2° hemorrhagic shock
1 from brain contusion
1 from anoxic brain damage
1 from hemorrhagic infarction 2° reanastomosed carotid artery.

117 patients underwent nonsurgical exploration whether or not they also had surgical exploration

136 patients underwent surgical exploration whether or not they also had nonsurgical exploration.

Fig. 1. Patient flowsheet. *Included in these 60 patients were 19 patients who underwent surgery as a result of positive findings on nonsurgical exploration.

nonsurgical exploration, there were 28 such signs and symptoms, or 0.49 per patient, while of 60 patients with negative surgical exploration, there were 38 such signs and symptoms, or 0.56 per patient.

Anatomic Structures Injured

The structures found injured either at surgery or autopsy are listed in Table 2. Major venous injuries were

**Table 1. Presenting Signs and Symptoms**

<table>
<thead>
<tr>
<th>Sign or Symptom</th>
<th>Negative Surgical Exploration*</th>
<th>Positive Surgical Exploration*</th>
<th>Nonsurgical Exploration Only†</th>
<th>Dead on Arrival‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vascular</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shock</td>
<td>8</td>
<td>18</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>Large amount of blood</td>
<td>3</td>
<td>12</td>
<td>3</td>
<td>—</td>
</tr>
<tr>
<td>Expanding or massive hematoma</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td>Obvious arterial bleed</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>Bruit</td>
<td>—</td>
<td>2</td>
<td>1§</td>
<td>—</td>
</tr>
<tr>
<td>Absent distal pulse</td>
<td>1</td>
<td>1</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Respiratory</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crepitance or subcutaneous air</td>
<td>7</td>
<td>18</td>
<td>3</td>
<td>—</td>
</tr>
<tr>
<td>Dyspnea</td>
<td>2</td>
<td>9</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>Airway obstruction</td>
<td>2</td>
<td>8</td>
<td>—</td>
<td>2</td>
</tr>
<tr>
<td>Air blowing from wound</td>
<td>—</td>
<td>5</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>Hemoptysis</td>
<td>1§</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Tracheal deviation</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>Visible trachea</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>Hoarseness</td>
<td>—</td>
<td>2</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hematemesis</td>
<td>—</td>
<td>8</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Dysphagia</td>
<td>3</td>
<td>2</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Blood in nasogastric tube</td>
<td>—</td>
<td>1</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Spinal or neural</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paraplegia or quadraplegia</td>
<td>—</td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Brachial plexus palsy</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td>Unresponsive or comatose</td>
<td>—</td>
<td>2</td>
<td>—</td>
<td>14</td>
</tr>
</tbody>
</table>

* No. of patients = 68.
† No. of patients = 57.
‡ No. of patients = 20.
§ In a patient with an unrecognized heart murmur and atherosclerotic vascular disease.

*Secondary to lung parenchyma injury from a multiple unrelated wound.
common, with 23 internal and 12 external jugular vein injuries found at surgery. A significant number of patients sustained major arterial injury, with nine common, five external, and four internal carotid artery injuries found at surgery, in addition to two vertebral artery and one subclavian artery injuries. Major visceral injuries were also common, with 11 tracheal, ten pharyngeal, nine esophageal, seven hypopharyngeal, and five laryngeal injuries found at surgery. A total of 17 patients sustained spinal cord laceration or transection. Eight of the nine patients with high level (C1 through C4) cord injury died, while none of the eight patients with lower level (C5 through T1) injury died.

**Clinical Indications for Surgery**

The primary indication given to justify surgery in those 136 patients who underwent surgical exploration is listed in Table 3. As with the presenting signs and symptoms, when specific clinical indications were absent and reasons such as location of the wound or penetration of the platysma muscle were listed as justification for surgery, there was a high degree of correlation with negative surgical exploration. Even when specific indications were present, not only did they occur in only a small total number of patients, but they are still associated with a proportionately significant number of negative explorations.

Figure 2 represents a flowchart for the above-mentioned patients. (It is coincidental that there were 76 patients with only surgical and 60 patients with both surgical and nonsurgical exploration, as well as 76 patients with clinical indications for surgery and 60 patients without. These are not the same subgroups of patients.) When the single specific clinical indications mentioned in Table 3 were considered as a group and surgery used as the gold standard of comparison, there were 53 true-positive, 45 true-negative, 15 false-positive, and 23 false-negative clinical in-
dications. For this group of primary indications, this yields a sensitivity of 78%, a specificity of 66%, and an overall accuracy of only 72%.

**Rate of Negative Surgical Exploration**

Of the 76 patients who underwent surgical exploration only, 42 were negative. Of the 60 patients who underwent both surgical and nonsurgical exploration, 26 were negative surgical explorations. Combining these groups yields 68 negative surgical explorations out of 136 total, for an overall 50% negative rate. The negative exploration rates for gunshot wound versus stabbing were fairly similar in this same group of 136 surgical patients. Fifty-four percent of the stab wounds and 45% of the gunshot wounds were surgically negative.

**Accuracy of Nonsurgical Procedures**

The number of times each of the nonsurgical explorations was performed is listed in Table 4. These procedures were performed singly and in combination. Accuracy of these nonsurgical procedures was assembled in two ways: by clinic follow-up of patients who had only nonsurgical exploration and by again using surgery as a standard of comparison in those patients who had both surgical and nonsurgical exploration.

Arteriography was performed a total of 74 times. Of the nonsurgical-exploration-only patients, 46 had negative and two had positive arteriograms in which no therapy was indicated: one had a laceration of a small branch of the transverse colic artery and one had an intimal nicking of the right vertebral artery with a 10% stenosis. None of these 48 patients had any delayed complication either due to the procedure itself or missed injury as documented by clinical follow-up. Of the patients with both surgical and nonsurgical exploration, using surgery as a standard yielded six true-positives, 20 true-negatives, and no false-positives or negatives. Overall, arteriography had a sensitivity, specificity, and accuracy of 100%.

Venography was only performed twice on patients who had only nonsurgical evaluation. Both venograms were negative, and neither of these patients had any delayed complication either due to missed injury or the procedure itself.

Contrast swallow esophagogram was performed a total of 41 times. Of the nonsurgical-exploration-only patients, 14 had only esophagogram, which was read as negative, and six had esophagogram and esophagoscopy, both of which were read as negative. None of these 20 patients had any delayed complication. Of the patients with both surgical and nonsurgical exploration, using surgery as the standard of comparison yielded four true-positives, 15 true-negatives, one false-positive, and one false-negative.

**Table 4. Incidence of Nonsurgical Procedures**

<table>
<thead>
<tr>
<th>Type of Procedure</th>
<th>Nonsurgical Exploration Only*</th>
<th>Both Surgical and Nonsurgical Exploration†</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arteriography</td>
<td>48</td>
<td>26</td>
<td>74</td>
</tr>
<tr>
<td>Esophagogram</td>
<td>20</td>
<td>21</td>
<td>41</td>
</tr>
<tr>
<td>Laryngoscopy</td>
<td>4</td>
<td>25</td>
<td>29</td>
</tr>
<tr>
<td>Bronchoscopy</td>
<td>11</td>
<td>18</td>
<td>29</td>
</tr>
<tr>
<td>Esophagoscopy</td>
<td>11</td>
<td>22</td>
<td>33</td>
</tr>
<tr>
<td>Venography</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

* No. of patients = 57.
† No. of patients = 60.
The false-negative esophagogram was diagnosed by esophagoscopy, while the false-positive was due to aspiration of contrast material with leakage from a tracheal perforation. Overall, contrast swallow esophagogram had a sensitivity of 80%, specificity of 94%, and accuracy of 90%.

Esophagoscopy was performed a total of 33 times. Of the nonsurgical-exploration-only patients, 11 had negative esophagoscopic examinations with no delayed complications. Of the patients with both surgical and nonsurgical exploration, using surgery as the standard yielded two true-positives, 17 true-negatives, two false-positives, and one false-negative. The false-positives included one examination that found blood in the esophagus without a discrete lesion and one examination that found a submucosa hematoma, while the false-negative was a 1 cm laceration not seen at esophagoscopy but seen and repaired at surgery. Overall, esophagoscopy had a sensitivity of 67%, specificity of 89%, and accuracy of 86%.

Bronchoscopy was performed a total of 29 times. Of the nonsurgical-exploration-only patients, nine had negative and two had questionably positive bronchoscopic exams. One had a small hematoma without mucosal damage, and one had submucosal edema with hematoma. None of these patients had any delayed complications. Of the patients with both nonsurgical and surgical exploration, using surgery as a standard yielded three true-positives, eight true-negatives, no false-positives, and seven false-negatives. One of the false-negatives was a tracheal laceration not seen at bronchoscopy because the endotracheal tube obscured the area of laceration, but this injury was also missed during exploratory surgery because the same tube prevented any bubbles from escaping during positive pressure ventilation. The other six false-negatives were all laryngeal or pharyngeal injuries including a lacerated pyriform sinus, a perforated aryepiglottic fold, a false cord laceration, a lacerated vallecula, a true cord avulsion, and a lacerated pharynx. However, all these six injuries missed at bronchoscopy were found prior to surgery during laryngoscopy. Overall, bronchoscopy had a sensitivity of 30%, specificity of 100%, and accuracy of 61%.

Laryngoscopy was performed a total of 29 times. Of the nonsurgical-exploration-only patients, two had negative and two had positive laryngoscopic exams not requiring surgery. One had edema with hematoma but no mucosal laceration, and one had a posterior pharyngeal injury. None of these four patients had any delayed complication. Of the patients with both surgical and nonsurgical exploration, using surgery as a standard yielded 11 true-positives, 11 true-negatives, two false-positives, and one false-negative. The two false-positives included one examination that found edema and hemorrhage but only minimal mucosal disruption and one examination that found blood in the pharynx without discernible mucosal damage. The false-negative was a laryngeal injury that was seen prior to surgery during bronchoscopy. In addition, three of the true-negatives were read as negative even though edema with ecchymosis was noted at the time of the examination. Overall, laryngoscopy had a sensitivity of 92%, specificity of 85%, and accuracy of 88%.

Except for one false-negative bronchoscopic exam in which the injury was also missed at surgery, in all of the false-negative bronchoscopic examinations the injury was found at laryngoscopy, and in the false negative laryngoscopic exam the injury was found at bronchoscopy. When bronchoscopy and laryngoscopy were used together and the exam not considered negative unless both were negative, out of 12 patients who had both, using surgery as a gold standard yielded seven true positives, five true negatives, and no false positives or negatives. Overall, this combination had a sensitivity, specificity, and accuracy of 100%.

Mortality

Of the 213 patients in the study, 28 died as a result of their injuries, for a total mortality rate of 13%. Excluding the 17 patients who succumbed in the accident room, of the 196 patients who survived long enough to be admitted to the hospital, 11 patients died, for a mortality rate of 5.6%. Finally, excluding three patients with high spinal cord transections on whom no therapy was indicated, eight patients died out of a total of 193, or 4.1%.

Of the 17 patients who were not successfully resuscitated, the cause of death was hemorrhagic shock in nine, high spinal cord transection and subsequent respiratory failure in six, and hemothorax in two. An additional three patients died from 4 to 46 days after admission from pneumonia and respiratory failure secondary to high spinal cord transection. Of the remaining eight deaths, two patients died during surgery from hemorrhagic shock, two died during surgery from myocardial infarction secondary to hemorrhagic shock, one died from a contrecoup brain contusion, one died from anoxic brain damage secondary to a transected trachea and respiratory arrest, one died of cerebral ischemic infarction secondary to a carotid artery bifurcation laceration, and one died of cerebral hemorrhagic infarction when a lacerated common carotid artery was surgically reanastomosed several hours post-injury (Fig. 1).

Morbidity

Of the 57 patients evaluated with only nonsurgical procedures, there were two complications, including a 10-day, postdischarge symptomatic anemia with a hematocrit of 22% and an unrelated femoral artery venous fistula from a second gunshot wound to the groin.
Of the 42 patients who had only surgical evaluation with a negative exploration, there were two complications, one an alpha-hemolytic streptococcal wound infection and the other an enterobacter wound infection. Of the 26 patients who had both surgical and nonsurgical evaluation and a negative surgical exploration, there were two complications each involving atelectasis with a postoperative fever.

Of the 34 patients who had only surgical evaluation with a positive exploration, there were eight complications, including an esophageal leak, an abscess, a chronic abscess, a nonhealing wound, three postoperative pneumothoraces requiring tube thoracostomy, and an unrelated pneumonia secondary to a multiple gunshot wound to the back. Of the 34 patients who had both surgical and surgical evaluation and a positive surgical exploration, there were two complications including a pseudomonal wound infection and an aspiration pneumonia.

Length of Hospital Stay

Of the 57 patients who underwent nonsurgical evaluation only, the average length of stay was 5.6 days. After correcting this value by eliminating three spinal cord injury patients and four patients with multiple serious injuries, the average length of stay was 2.8 days. Of the 42 patients who had surgical evaluation only and a negative exploration, the average length of stay was 4.5 days. After correcting this value by eliminating two patients with multiple serious injuries, the average length of stay was 4.2 days. Of the 34 patients who had surgical evaluation only and a positive exploration, the average length of stay was 15.8 days. After correcting this value by eliminating two spinal cord injury patients, two multiple serious injuries, and a patient transferred to another hospital for psychiatric care, the average length of stay was 9.5 days. The average length of stay for all nine spinal cord injury patients was 85.4 days.

Financial Cost of Treatment

Using figures obtained from Tulane Medical Center, a private hospital in New Orleans, if a patient were admitted through the emergency room, taken to the operating room, surgically explored for 2 hours of operating time, and stayed in the hospital in a semiprivate room for 4.5 days, the cost to the patient would be $3185. This represents the cost of a negative surgical exploration. If the same patient were admitted through the emergency room, taken to the radiology suite where he underwent four-vessel cerebral arteriography, taken to the operating room where he underwent bronchoscopy, laryngoscopy, esophagoscopy, and stayed in the hospital 2.8 days, the net cost to the patient would be $3492. Arteriography accounts for $1140 and panendoscopy $677 of this total. This represents the cost of a negative nonsurgical exploration. Obviously, if a nonsurgical exploration was positive, the patient would then undergo and be charged for the subsequent surgery.

Discussion

There is little disagreement among authors that unstable patients or those exhibiting "obvious" signs or symptoms of vascular or visceral damage must undergo surgery. As these data show, however, even these patients will undergo a certain number of negative surgical explorations: of 76 patients with a specific clinical indication for surgery, there were 23 negative surgical explorations (Fig. 2). The disagreement primarily occurs in the management of relatively asymptomatic patients or those with minor or nonspecific signs and symptoms. Some authors maintain that certain carefully selected patients can be safely observed, while others advocate near-mandatory surgical exploration of all wounds that penetrate the platysma. Each policy has both advantages and disadvantages, a discussion of which follows.

Those authors who advocate a policy of passive observation of selected patients base their selection in part on the presence or absence of certain signs and symptoms as an indication of injury. This study as well as a review of the literature, however, demonstrates the woeful inadequacy of signs and symptoms as a predicting factor for the presence and degree of injury.2,3,6,18-21 The problem arises because sensitive signs often occur in the absence of injury, while specific signs occur only in a small total number of patients. In this study, for example, of 26 patients in shock who underwent surgery, eight underwent negative explorations; and, while all five patients with air blowing from their wound had positive explorations, this number of patients represents only a small portion of the 16 patients with tracheal or laryngeal injuries, let alone the 68 patients with positive explorations (Table 1). Consistently, however, most authors who advocate observation do so in part because of the presence or absence of various signs and symptoms.9-16,22

There is also little argument regarding the serious morbidity and occasional mortality associated with missed vascular or visceral injury. Given this fact, it is surprising that a careful review of the authors advocating selective observation reveals several instances of patients who were passively observed subsequently developing major complications from missed injuries. Defore et al., in a review of 77 penetrating esophageal injuries, reported three patients who were initially observed and subsequently required reoperation.21 Shirkey et al., in a review of 225 penetrating wounds to the neck, of which 65 were observed, found two deaths secondary to missed esophageal injuries.22 Sheely et al., in a study of 632 patients, found
three deaths from missed esophageal injuries in 125 observed patients.10 Stein and Seaward, in a study of 200 penetrating neck wounds, of which 133 were passively observed, found one missed esophageal injury that subsequently had to undergo surgical decortication of a thoracic empyema.9 Markey et al., in a study of 218 penetrating wounds of the neck, of which 38 were observed, found six complications including an arteriovenous (AV) fistula.2 Massac et al., in a study of 120 penetrating wounds of the neck, of which 59 were found, observed two patients needing subsequent reoperation including one for an AV fistula.12 Whether these complications were in part secondary to undue reliance on signs and symptoms is a matter of conjecture.

It is of paramount importance to avoid these complications from missed injuries. This is the primary reason why most authors advocate mandatory surgical exploration of all wounds deep enough to penetrate the platysma, as surgery is considered to be the most accurate method of diagnosing anatomical injury.21,23 The cost of such a policy is, of course, a high rate of negative explorations. In this study, of 136 patients with surgical exploration, 68 or 50% were negative. In those studies advocating mandatory surgical exploration, the rate of negative exploration ranged from 27% to 63%.1-8 Nearly all studies advocating mandatory surgical exploration accept this high negative rate as being only rarely associated with significant morbidity and no mortality, especially when compared to the morbidity and mortality associated with a missed injury. In a theoretical sense, however, it represents the number of patients who might have been spared the risks of unnecessary surgery if a reliable diagnosis were possible without surgery.

While low, this morbidity is by no means insignificant and deserves further comment. To assess this morbidity, many studies have compared the complication rate for surgical exploration versus observation. However, this must be done carefully, as it inherently suffers from two problems. One lies with the difficulty in distinguishing between morbidity and mortality associated with the surgical procedure versus the initial injury itself; the other lies in the fact that studies advocating selective observation have excluded from the observed group the most seriously injured patients as they undergo immediate surgery, leading to a group of observed patients who are not nearly as severely injured as their surgically explored counterparts. This introduces a large amount of bias into the study, as it is only to be expected that a significant amount of morbidity and mortality will be associated with the degree of initial injury and not to the method of management.

The only way to assess accurately the morbidity associated only with surgery is to examine those patients who underwent negative surgical explorations. Any resulting morbidity can then safely be ascribed to the surgery itself. Of the 68 patients in this study with negative explorations, there were two wound infections, with significantly increased hospital stays of 10 and 18 days each. This is compared to an average of 4.5 days for all negative surgical explorations. Markey et al. found 12 minor complications in 69 patients with negative surgical explorations.2 Jones et al. reported one wound infection in 103 patients with negative surgical explorations.3 Saletta et al. found one wound infection in 156 patients with negative explorations.6

With regard to the second problem, unlike some other studies, the patients in this study with negative nonsurgical explorations had nearly the same number of serious presenting signs and symptoms suggestive of injury (0.49 per patient) as those patients who underwent negative surgical exploration (0.56 per patient). In addition, 17 patients underwent surgery only after positive findings on prior nonsurgical exploration.

Another common complaint with some of the studies advocating selective observation is the very high percentage of stab wounds versus gunshot wounds.9,13 In this study, 40% were gunshot wounds, and the overall incidence of negative findings was similar for gunshot versus stabbing; gunshots were 45% surgically negative versus 54% for stabblings.

An acceptable alternative to this dilemma would be a method of accurately diagnosing the presence or absence of injury without increasing morbidity or mortality and without subjecting the majority of patients to surgery that in retrospect they would not have needed. A combination of arteriography and panendoscopy might provide just such a method.

Of primary concern is the accuracy of nonsurgical exploration versus surgery. In this study, arteriography was 100% accurate, with no false-negative or false-positive findings. In a review of the literature, no instances of false-negative angiographic examination were found.16,17,24,25 However, the literature cites many instances of arterial injury missed initially at surgical exploration, usually with major morbidity and occasional mortality. Massac et al. reported a patient who needed reoperation after neurologic deficit developed and a postoperative angiogram showed carotid artery laceration.12 Penn reported a patient who developed severe shock and massive hemothorax 5 days after exploratory surgery failed to reveal a common carotid artery injury. This patient had two subsequent operations: a re-exploration and a clotted hemothorax decortication.4 Saletta et al. found two patients who underwent re-exploration after missed arterial injuries.6 Weaver et al., in a study of 221 patients, of whom 178 were surgically explored, reported one patient who exsanguinated from a missed carotid artery injury, one patient who died from a thrombosed carotid artery with no apparent external injury, and one with a missed innominate
artery injury that required reoperation.\textsuperscript{5} Monson et al. reported a patient who developed progressing neurological signs after a negative surgical exploration and was found at arteriography to have an intimal disruption and thrombosis requiring reoperation.\textsuperscript{25}

While arteriography is not a benign procedure, in this study of 74 arteriograms, there were no complications associated with the procedure. The literature values for complications are low, and even these are somewhat artificially elevated because of the prior poor medical condition of the patients. Hessel et al., in a study of 83,068 transfemoral arteriograms, found a complication rate of 1.73\% and a death rate of 0.03\%.\textsuperscript{26} Obviously, because of the very real risk to the trauma patient of acute decompensation during arteriography, only stable patients should be allowed the time necessary to perform the procedure. McCormick and Burch estimated that the time spent in radiology for neck and extremity injuries was seldom more than 60 minutes.\textsuperscript{19} Sankaran and Walt state that more than 90\% of patients with neck wounds are in sufficiently satisfactory condition to undergo arteriography.\textsuperscript{27} It seems clear that for those stable patients who can afford this time, arteriography is a more reliable method of diagnosing arterial injuries, especially for intimal disruption or thrombosis. In addition to this reliability, a significant advantage of arteriography is that in the event of a positive finding, it is easier to plan the operative approach, either in anticipation of extending the incision into the thorax or in dealing with injuries at the base of the skull.\textsuperscript{5,27,28}

Venography was only used twice, with negative results each time. There were no complications from missed diagnoses in either. There were no reports in the literature detailing the use or accuracy of venography in cervical trauma, which is surprising given the high incidence of major venous injury, 23 internal and 12 external jugular vein injuries in this study. This may be due to the fact that initial hematoma formation after venous injury leads to hemostasis and consequently a high rate of false-negative venography.\textsuperscript{29} Whether missed venous injuries result in morbidity or mortality has not been reported in the literature.

When bronchoscopy and laryngoscopy were used together, they were 100\% accurate at diagnosing tracheal or laryngeal injuries. They were not as useful when used singly, however, as was discussed above. In a study of 20 penetrating tracheal injuries, Symbas et al. reported nine true-positive and no false-negative tracheoscopic examinations.\textsuperscript{30} Worth repeating is the fact that one of the patients in this study had two reoperations as a result of a tracheal injury that was missed both at surgery and bronchoscopy because of interference from an endotracheal tube. As with other structures, surgery should not be considered infallible either. Jones et al. reported two mortalities from missed tracheal injuries, one of which they felt might have been prevented if bronchoscopy had been performed.\textsuperscript{3} This study supports the fact that a combination of bronchoscopy with laryngoscopy is a reliable method of nonsurgical diagnosis and, like arteriography, has distinct advantages in the event of subsequent surgery. Besides helping delineate the site and extent of injury, it also allows for the lavage and aspiration of blood or other fluids from the tracheobronchial tree.\textsuperscript{3,31,32}

Probably no greater controversy exists regarding penetrating wounds of the neck than in the diagnosis and management of esophageal injuries. This is primarily related to the tremendous morbidity and mortality associated with missed injury and subsequent sepsis as well as the problems associated with all forms of diagnosis: esophagogram, esophagoscopy, and surgery. In this study, esophagogram was 90\% accurate, with one false-positive and one false-negative examination. The false-negative was diagnosed by esophagoscopy, whereas the false-positive was due to aspiration and leakage from a tracheal perforation. This is significant in light of the current opinion regarding esophagography, that a negative examination does not rule out injury, but a positive examination confirms it.\textsuperscript{33} The literature values for accuracy of esophagograms are well documented and vary widely, with authors reporting false-negative rates averaging from 0\% (nine positive out of nine performed on documented esophageal injuries) to 79\% (three positive out of 14).\textsuperscript{17,20,21,23,33,34} One study found that all three deaths from esophageal wounds were secondary to undue reliance on negative esophagograms.\textsuperscript{33}

This study found esophagoscopy to be 86\% accurate in the 22 times that it was performed with surgery as a control. There were two false-positive and one false-negative examinations. The false-positive examinations involved blood or hematoma with no discrete lesion found either during esophagography or surgery. The false-negative was a laceration found at surgery. Many authors advocate the use of esophagoscopy but provide no data regarding its accuracy.\textsuperscript{18,30,35} Of those who do, the literature values for accuracy of esophagoscopy also vary widely (Table 5). Of note is the general trend over the last 17 years toward more accurate esophagoscopy. This may in part be due to increased use of the flexible fiberoptic scope.\textsuperscript{33}

It deserves re-emphasis that, while surgery was used as a gold standard of comparison in this study, it by no means should be considered 100\% accurate. Knightly et al. reported that one out of three esophageal injuries missed at surgery developed bilateral cervical abscesses requiring drainage.\textsuperscript{7} Weaver et al. reported two injuries missed at surgery out of 12 esophageal injuries, each requiring secondary drainage.\textsuperscript{5} Spenler and Benfield, out of 11 esophageal injuries, found that one missed at surgery required drainage.\textsuperscript{34} Symbas et al. reported a patient whose esoph-
ageal perforation initially missed at surgery was seen at esophagoscopy. They felt that one possible reason for this and other missed injuries was due to the necessity of dissecting the esophagus free from the mediastinal structures to see the injury or to observe air or methylene blue extravasating from the wound. Cheadle and Richardson feel that esophagoscopy is especially warranted because blood staining of the cervical tissues from hematoma may conceal evidence of an esophageal injury at surgery.

Like arteriography, esophagoscopy is not an entirely benign procedure, but the literature values for serious complications such as iatrogenic perforation are low and are usually associated with predisposing factors such as malignancy or strictures. Michel et al. reported a 0.04% iatrogenic perforation rate with 0.005% mortality, but only one of their eight patients had no predisposing factors. (These figures were interpolated from their combined data regarding esophagoscopy and esophageal dilatation.) These figures can, if anything, be expected to decline with increased use of the flexible fiberoptic scope and its use by more experienced endoscopists.

One caution when dealing with endoscopy is the presence of edema, blood, or hematoma without specific mucosal laceration. One possible etiology for this type of injury is the somewhat “blunt” nature of penetrating trauma, especially of the low velocity gunshot wounds found in civilian practice. This occurred in two of 33 esophagogoscopic, two of 29 bronchoscopic, and six of 29 laryngoscopic examinations. None of these findings was associated with positive surgical examination or, when surgery was not performed, with delayed complication from missed injury. The finding of hematoma without mucosal laceration was much more common in laryngeal and tracheal rather than esophageal injuries. This may in part be due to the more rigid nature of these strictures and their propensity to contuse upon injury rather than simply be pushed out of the way. However, because of the disastrous complications associated with missed injury, special care must be taken to rule out mucosal perforation. Ordog et al. considered esophagoscopy to be positive with hematoma. Sheely et al. reported ten injuries to the esophagus involving the muscularis but not the mucosa that were treated as perforation out of concern that perforation might occur or a diverticulum develop, though this concern was only speculative.

In this study, nonsurgical exploration was associated with a significant reduction in length of stay, 2.8 days versus 4.5 days for a negative surgical exploration. Several authors have reported lengths of stay for surgical exploration ranging from 4.5 to 10 days, but these included positive explorations, and again the problem of separating original injury from surgery arises. This study closely agrees with others who have reported lengths of stay from 3 to 6.8 days for patients with negative surgical exploration only. Figures for patients who were observed vary widely, however, from 1.5 to 7 days. Some authors even reported longer lengths of stay for observed patients than for negative surgical patients.

Surgical exploration was associated with a slightly lower financial cost than was nonsurgical exploration: $3185 versus $3492. This difference is actually underestimated, as those patients with positive nonsurgical findings must then undergo the cost of surgery. Only one author has published data detailing the cost of exploration of penetrating neck wounds. Merion et al. reported the cost of surgery as being $1930, while nonsurgical exploration was $877. Not included in this figure, however, was the cost of endoscopy, which for the patients in this study would have been $677.

**Conclusion**

Although more studies need to be done, particularly regarding venography and esophagoscopy, the data in this study support the fact that, compared to mandatory surgical exploration, arteriography with panendoscopy represents an equally safe and acceptable method of initial exploration for stable patients with penetrating wounds of the neck. While its accuracy is approximately equal to that of surgery, it is associated with a reduced rate of negative surgical exploration, less accompanying morbidity, and a decreased length of hospital stay, although at a slightly higher financial cost.

**References**