Computed Tomography in the Evaluation of Penetrating Neck Trauma

A Preliminary Study

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Hypothesis: Penetrating neck trauma has traditionally been evaluated by surgical exploration and/or invasive diagnostic studies. We hypothesized that computed tomography (CT), used as an early diagnostic tool to accurately determine trajectory, would direct or eliminate further studies or procedures in stable patients with penetrating neck trauma.

Design: Retrospective case series.

Setting: Academic, urban, level I trauma center.

Patients: Hemodynamically stable patients without hard signs of vascular injury or aerodigestive violation who had sustained penetrating trauma to the neck.

Interventions: Patients underwent a spiral CT as an initial diagnostic study after initial evaluation in the trauma bay. Further invasive studies were directed by CT findings.

Main Outcome Measures: Number of invasive studies performed.

Results: Twenty-three patients were identified during the 30-month period. Nineteen patients sustained gunshot wounds; 3, shotgun wounds; and 1, a stab wound. One patient died of a cranial gunshot wound. Three isolated zone I, 1 isolated zone II, 9 isolated zone III, and 10 multiple neck zone trajectories were evaluated. Thirteen patients were identified by CT to have trajectories remote from vital structures and required no further evaluation. Ten patients underwent angiography. Only 2 underwent bronchoscopy and esophagoscopy. Four patients were discharged from the emergency department; 7 other patients were discharged within 24 hours. No adverse patient events occurred before, during, or after CT scan.

Conclusions: Computed tomography in stable selected patients with penetrating neck trauma appears safe. Invasive studies can often be eliminated from the diagnostic algorithm when CT demonstrates trajectories remote from vital structures. As a result, efficient evaluation and early discharge from the trauma bay or emergency department can be realized. Further prospective study of CT scan after penetrating neck trauma is needed.

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Penetrating neck trauma can pose difficult diagnostic dilemmas in the verification of injury. Surgical exploration for deep zone II injuries or protracted noninvasive studies involving angiography and endoscopy have been traditionally used to triage and treat these injuries. Recently, a more conservative observational approach using physical examination for penetrating neck injury has been suggested. In contrast to the widely practiced noninvasive evaluation of lower extremity penetrating trauma, the concern over occult neck injury, especially vascular injuries of the carotid or vertebral arteries and the inherent cerebral sequelae, has led to considerably less acceptance of noninvasive evaluation of penetrating neck trauma. This, combined with the concern regarding patients with multiple wounding patterns and multiple zone penetration, has encouraged us to identify an intermediate approach between physical examination alone and invasive studies and/or surgical exploration.

Recently, the role of computed tomography (CT) in the evaluation of patients with penetrating trauma to the abdomen, flank, chest, and mediastinum has been described. The emergence of helical CT scanning with greater speed and resolution may offer a reasonable method of triaging penetrating neck injury. In selected patients, we have begun using CT scan to determine exact trajectory and identify injuries after penetrating trauma.
Patients who had sustained penetrating neck trauma were evaluated in the trauma resuscitation bay. Patients who were determined to be hemodynamically stable by an in-house faculty trauma surgeon and lacked “hard” signs of vascular injury (ie, arterial bleeding, expanding hematoma, bruit, or airway compromise) were evaluated by spiral CT. This CT of the neck was performed as a primary diagnostic tool before any further studies.

The CT scanner used was a General Electric CTi spiral scanner (General Electric, Milwaukee, Wis). The contrast infusion protocol included a 150-mL contrast (Iopaque ionic contrast) delivered by rapid infusion at a rate of 2 mL/s through a large-bore antecubital intravenous tube. Radiographs were obtained at 3-mm intervals from the base of skull (level of clivus and mastoid air cells) to the top of the aortic arch. Both faculty radiologists (4 physicians) and attending trauma surgeons (6 surgeons) on call immediately interpreted all CT scans at digital monitoring stations within the emergency center.

Trajectory determination was performed by identifying the skin entry site for each neck wound with metallic markers and following the wound tract as it coursed through multiple slices of the scan. The helical CT scan findings to delineate missile trajectory and organ injury included the following: skin violation, subcutaneous fat stranding, soft tissue air or hemotoma, vertebral fracture, contrast extravasation, and missile location. In general, these wound tracts were easily identifiable on CT imaging. The aerodigestive, vascular, and neurologic anatomic structures of the neck were also clearly visualized by CT, and proximity to the trajectory path of these critical structures was determined. In cases where the trajectory path was found to travel in a close proximity to vital neck anatomic structures, targeted invasive (and/or noninvasive) studies were then undertaken as guided by the CT imaging to definitively exclude injury to those structures believed to be at increased risk.

Demographic data, injuries identified, neck zone involvement, and further diagnostic studies were abstracted for the study group. Times from presentation to CT scan and other studies were recorded, as was the time in CT scan and the hospital length of stay. Where appropriate, results are presented as mean ± SEM.

to the neck. We observed that the use of CT accurately delineated occult injury and quickly identified patients in need of exploration and those who required no further workup. We retrospectively reviewed our experience with CT as an early diagnostic modality to direct or eliminate further invasive studies in selected stable patients with penetrating neck injury.

**RESULTS**

A total of 68 patients with penetrating injury to the neck were identified during this period. Twenty-three (34%) of these patients were determined to be stable without

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**Table. Resuscitation Times for Study Group**

<table>
<thead>
<tr>
<th>Description</th>
<th>Mean ± SEM</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time in computed tomography, min</td>
<td>31 ± 3</td>
<td>23</td>
</tr>
<tr>
<td>Presentation to computed tomography, min</td>
<td>56 ± 20</td>
<td>23</td>
</tr>
<tr>
<td>Presentation to invasive studies, min</td>
<td>274 ± 42</td>
<td>10</td>
</tr>
<tr>
<td>Length of stay, d</td>
<td>4 ± 1.5</td>
<td>19*</td>
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</tbody>
</table>

*Four patients were discharged from the emergency department.

hard signs of vascular injury but at risk for injury to vital structures within the neck and had a CT scan of the neck performed as a primary diagnostic modality. These 23 patients represent the study group.

Nineteen (83%) of the 23 patients sustained gunshot wounds, 3 patients (13%) sustained shotgun wounds, and 1 patient (4%) sustained a stab wound. One patient died of a concomitant but separate cranial gunshot wound. Demographic data are consistent with our overall urban penetrating trauma population. The study group largely consisted of young men (87%), with a mean age of 29 ± 2 years. Ten patients (43%) were determined to have trajectories, which violated multiple neck zones. All 10 patients sustained zone II penetration, 2 patients had zones I and II violated, 6 patients had zones II and III violated, and 2 patients sustained penetration of all 3 zones. The most common isolated neck zone trajectory in the study group was zone III penetration, as seen in 9 of the 23 patients. The mean Injury Severity Score was 13 ± 3.

The mean time from presentation to the emergency department until the commencement of the CT scan was 56 minutes (Table). The CT scan itself took approximately 30 minutes. No adverse patient events occurred before or during CT scan. Ten patients underwent further invasive studies as directed by CT scan results. All 10 of these patients underwent angiography, and 2 of the 10 patients also underwent esophagoscopy and bronchoscopy. The mean time from emergency department presentation until the performance of these invasive studies was 274 minutes.

Three vertebral artery injuries were identified, 2 of which required embolization (2 patients with zone III injury and 1 patient with zone II injury). One injury to a branch vessel of the left subclavian artery was confirmed and treated by embolization. One ophthalmic vein injury was identified (zone II) and managed nonoperatively with no subsequent complications noted. There were 6 facial and 6 spinal fractures, 2 intercranial hemorrhages, and 4 hemopneumothoraces. Of note, only the findings of hemothorax or pneumothorax (identified on initial chest x-ray examination) were identified before CT scan. No esophageal or tracheal injuries were identified endoscopically on either patient studied. Spine injuries identified involved all zones.

Four (17%) of the 23 patients were discharged from the emergency department, and an additional 7 were discharged within 24 hours. Patients admitted for observation generally had associated injuries requiring admis-
et al13 confirmed these findings in a second study that relied on invasive diagnostic procedures. Later that year, Ginzburg et al10 independently concluded that accurate initial trajectory determination in patients with penetrating injuries streamlined the subsequent management and avoided unnecessary invasive testing.

Our findings duplicate those of these studies in a group of 23 hemodynamically stable patients with penetrating neck injury who were immediately studied with CT scan of the neck. Many of these patients had multiple zone injuries, making physical examination difficult and unreliable. Helical CT scanning proved to be an accurate and rapid method of evaluating trajectory and precisely directing further therapy (Figure 1 and Figure 2). In 13 of the 23 patients, CT scan effectively ruled out trajectories consistent with injury to the aerodigestive tract or major vascular structures. Four of these patients were discharged from the emergency department without the need for further in-hospital observation. Seven additional patients were discharged following brief periods of observation. Ten patients received invasive studies targeted to further delineate or treat active injuries. All 10 patients underwent angiography, most often for concern of vertebral artery injury. Only 2 patients required aerodigestive evaluation with endoscopy due to proximity of penetrating injury as seen on CT scan. No patient experienced an adverse event or needed the study truncated because of a physiologic change or the onset of bleeding.

Traditionally, hemodynamically stable patients with injuries to zones I and III have been managed with angiography and endoscopy. Conversely, zone II injuries have been managed by operative exploration. Although this approach has yielded relatively few complications, it is a nonspecific treatment algorithm that carries a high rate of negative and nontherapeutic outcomes. Approximately one fifth of explorations for zone II injuries will be nontherapeutic.1-6 Furthermore, significant expense, labor, and possibly morbidity are associated with the often negative invasive studies that result from the evaluation of zone I and III penetrations.1-6 The lack of precision inherent in the traditional protocol developed before missile wound tracts could be clearly evaluated with CT scan. This represents a major shortcoming in the traditional management protocol and escalates the potential for overuse of invasive testing. To date, no studies have demonstrated an alternative method to evaluate penetrating neck injury with similar sensitivity and specificity. Accordingly, most trauma surgeons practice selective management and liberally use angiography and endoscopy in stable patients.

The results of this study, pending confirmation by a larger prospective study, must be taken with a cautionary note. However, our findings are similar to other experiences with the use of CT scanning in selected patients with penetrating injury to other anatomic areas.1-6,14

In all these reports, the CT scan is rapid, accurate, and precise in delineating trajectory and injury. The selection of patients is key, and when selected properly, the use of CT scan as an immediate diagnostic test is safe. In

Three-dimensional determination of missile trajectory and its proximity to vital anatomic structures by CT has proven to be extremely valuable in the immediate management of hemodynamically stable patients with penetrating injuries. This concept has been applied in multiple anatomical regions and has improved the precision, specificity, and appropriateness of the ensuing workup.10-14 A missile trajectory course that is distant to vital anatomic structures can obviate further operative intervention and/or invasive testing and allows for an abbreviated observation period and early discharge. A missile trajectory that is in close proximity to vital structures precisely identifies a limited, specific set of anatomic structures that can be targeted with specific invasive studies to clarify the presence of injury. Finally, a missile trajectory involving a critical structure can frequently eliminate delays to the operating room and help plan operative management. The phrase, “Accurate trajectory determination equals injury identification,” has become an axiom at this institution as well as others and is appropriate in describing the utility of carefully mapping out missile trajectory paths in patients with penetrating injuries.

This concept is not a new one. In 1997, Demetriades et al10 suggested the application of missile trajectory determination and clinical examination in assessing potential for peritoneal penetration in the decision of whether to manage of gunshot wounds to the abdomen operatively or nonoperatively. Later that same year, Velmahos et al11 reported the successful nonoperative management of penetrating flank wounds based on missile trajectory determination and clinical examination. In 1998, Grossman et al12 reported that the dedicated trajectory mapping in 3 dimensions using high-resolution helical CT scanning for hemodynamically stable patients with torso gunshot wounds streamlined the subsequent management and reduced the incidence of invasive diagnostic procedures. Later that year, Ginzburg et al13 confirmed these findings in a second study that successfully used dedicated trajectory mapping of missile wound tracts as determined by high-resolution CT scanning in hemodynamically stable patients with gunshot wounds to the abdomen and flank. These authors were able to accurately document the presence or absence of peritoneal penetration and better manage stable patients with liver injuries. Most recently, Hanpeter et al14 published their experience applying high-resolution helical CT to patients with transmediastinal gunshot wounds to accurately assess the potential for mediastinal injury. They reported a reduced need for routine angiographic and esophageal studies. In these last 3 studies in which CT was specifically used as an initial screening test for the purpose of trajectory determination, all 3 investigators showed that the initial determina-

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our own institution, we observed the following: (1) the traditional workup of neck injuries based on historical neck zone classifications was abandoned once CT scan demonstrated a missile trajectory distant to vital neck structures and (2) a more focused diagnostic approach was used based on the CT scan information and only targeted studies performed. These observations parallel those of Hanpeter et al in their evaluation of CT in stable patients with transmediastinal missile injuries.

Although the use of CT scan is associated with a finite cost, overall it would appear to be a cost-efficient use of readily available routine technology. The elimination of arteriography in more than 50% of the present patient population, and endoscopy in more than 90%,
offs...m... that incurred with the use of CT. The potential decrease in the need for hospital admission or a decreased hospital length of stay makes the cost savings of early CT scan of the penetrated neck even more substantial.

The sensitivity of helical CT scanning for the detection of vascular injuries in patients with penetrating neck wounds has recently been addressed by Munera et al. This study compared the accuracy of helical CT angiography with conventional angiography in patients with penetrating neck injuries and found helical scanning with intravenous contrast to be highly accurate. In this study of helical CT angiography, the sensitivity was 90%, the specificity was 100%, the positive predictive value was 100%, and the negative predictive value was 98%. The one missed injury in this series, a small pseudoaneurysm at the origin of the common carotid artery detected on conventional angiography, resulted from not including the origin of the right common carotid artery in the region evaluated at helical CT. The authors note that if they had scanned from the base of the skull to the top of the aortic arch (as performed in the present study), they would have had a 100% value for sensitivity and negative predictive value.

The present study is limited by the small number of patients reviewed. However, during the study period there was a stable, single in-house faculty group that treated all patients with common practice patterns. This group has a lengthy and extensive experience with CT scan use and penetrating injury management. Only one third of the patients with penetrating neck trauma were considered appropriate for evaluation by CT scanning. Clearly, the role of CT in this population, although important, is limited to a subset of stable patients who have no hard signs of anatomic injury to the vascular or aerodigestive system.

The results of the present study indicate that, in hemodynamically stable patients with penetrating neck injuries, initial trajectory and injury determination with helical CT produced the critical information necessary to streamline diagnosis and expedite management decisions. This makes helical CT an attractive primary diagnostic modality for evaluating selected patients with penetrating neck injury. Further prospective study of this novel approach in the management of penetrating neck injuries is warranted.

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REFERENCES