Evaluation of multidetector computed tomography for penetrating neck injury: A prospective multicenter study

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Author Disclosures:

All authors have nothing to disclose.

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BACKGROUND: The purpose of this prospective multicenter study was to evaluate a clinical protocol integrating multidetector computed tomographic angiography (MDCTA) as the initial screening examination for the work-up of penetrating neck injury.

METHODS: All penetrating neck injuries assessed at two Level I trauma centers (January 2009-July 2011) prospectively underwent a structured clinical examination. Those with hard signs of injury (active bleed, instability, expanding/pulsatile hematoma, bruit/thrill, hemoptysis, hematemesis, and air bubbling) underwent exploration, those who were asymptomatic were observed. The remainder, with soft signs underwent MDCTA. Sensitivity and specificity were tested against an aggregate gold standard of operative intervention, clinical follow-up, and when obtained, conventional angiography, bronchoscopy, esophagogram, and esophagoscopy.

RESULTS: Four hundred fifty-three penetrating neck injuries were evaluated. Hard signs of vascular or aerodigestive tract injury were observed in 8.6% with an 89.7% incidence of clinically significant injury. 41.7% had no signs of injury and were observed with no missed injuries (follow-up, 2.6 days ± 1.1 days [1–58 days]). The remaining 225 (49.7%) underwent MDCTA (stab wound, 61.3%; gunshot wound, 37.8%; shotgun, 0.9%). The external wounds were in zone II (38.2%), multiple (28.9%), zone I (16.9%), and zone III (16.0%). Twenty-eight injuries were found in 22 patients (5 internal jugular-V, 2 external jugular-V, 1 vertebral-A, 7 common carotid-A, 2 internal carotid-A, 3 external carotid-A, 2 subclavian-A, 3 esophagus, and 3 tracheas). Five patients had false-positive findings (2 vascular and 3 aerodigestive tract). The 194 negative studies (follow-up, 5.5 days ± 7.5 days [1–27 days]) had no delayed diagnosis of injury. MDCTA was nondiagnostic in four patients (1.8%), secondary to artifact. One of these had a vertebral-A injury diagnosed at angiography. MDCTA achieved 100% sensitivity and 97.5% specificity in detecting all clinically significant injuries.

CONCLUSION: In the initial evaluation of patients who have sustained penetrating neck trauma, physical examination can safely reduce unnecessary imaging. If imaging is required, MDCTA is a highly sensitive and specific screening modality for evaluating the vascular and aerodigestive structures in the neck. (*J Trauma.* 2012;72: 576–584. Copyright © 2012 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: II, prospective study.

KEY WORDS: Penetrating neck trauma; vascular injuries; aerodigestive injuries; diagnostic imaging; computed tomography angiography; multidetector CT.

The diagnostic strategy for patients sustaining a penetrating injury to the neck has undergone significant change, driven in part by the introduction of multidetector computed tomographic angiography (MDCTA). For patients who are unstable or have clear evidence of a vascular or aerodigestive tract injury, operative exploration is indicated. For those without, traditional management options[1–12] included mandatory exploration, mandatory imaging, or a hybrid diagnostic algorithm that used physical examination to direct imaging. Mandatory exploration was less than optimal as there was a high rate of negative exploration. Similarly, mandatory imaging was also difficult to justify because of the significant resource implications associated with the low yield testing, which included conventional catheter-based angiography, endoscopy, and esophagogram. As a result, selective, physical examination directed imaging was a common practice. This was based on the anatomic location of the external gunshot or stab wound (SW). Three zones were described based on the surgical accessibility of the underlying vascular and aerodigestive tract structures. Because injuries in zone II were easily accessible, surgical exploration was used liberally for injuries in this area. With zones I and III however, as they encompassed vascular structures high up in the neck and low down in the thoracic inlet with exposure challenges, whenever possible, imaging was obtained. The practical implementation of this diagnostic strategy, however, was made difficult by several factors. First, the location of the external wound does not necessarily correlate to where the underlying injury is located. Thus, it is conceivable for example that a zone II gunshot wound that is assumed to be easily accessible has actually caused a vascular injury in zone I or III where preoperative imaging and even an endovascular approach would have been advisable. Second, with the extensive battery of tests required, the traditional diagnostic work-up for zone I and III injuries remains both time and resource intensive.

This has all changed with the increasing availability of MDCTA.[13–23] With widespread availability around the clock without the need for mobilizing an angiography team and using preexisting hardware, software, and contrast injectors, this technology has been used extensively in the diagnostic work-up of the injured patient. Practically, there are numerous advantages for the clinical team. The patient is not under a sterile field and is easily accessed, allowing for close monitoring. The technology provides rapid data acquisition and postprocessing, minimizing the time spent in radiology. Not only are the vascular and aerodigestive tracts imaged with a single examination, but the surrounding soft tissue and bony cervical spine is also evaluated with high resolution, multiplanar, three-dimensional operator independent images that are surgeon friendly. The contrast load is comparable to four vessel runoff angiography and is given peripherally without the need for central arterial access. Finally, although variable and dependent on the protocol used, in studies

Submitted: September 30, 2011, Received: November 30, 2011, Accepted: December 5, 2011.
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DOI: 10.1097/TA.0b013e31824badf7

performed for the lower extremities, computed tomographic (CT) angiography has been demonstrated to be effective in lowering the radiation burden when compared with conventional angiography.[24]

With MDCTA integrated into the diagnostic algorithm, the neck can now be considered as a unit and physical examination can be used to triage patients regardless of the zone of injury. Those with instability or hard signs of injury still proceed directly to the operating room (OR). Those that are asymptomatic with no signs of injury are observed. The remainder, with soft signs of injury can then be evaluated with screening MDCTA. A positive finding on the MDCTA prompts intervention and a negative MDCTA results in observation leaving only those patients with an equivocal MDCTA for example from retained missile fragments, to go onto the traditional battery of tests.

The purpose of this prospective multicenter study was to evaluate a clinical algorithm integrating physical examination and MDCTA as the initial screening examination for the work-up of penetrating neck injuries. Our hypothesis was that (1) physical examination is effective for reducing the need for unnecessary imaging and (2) that MDCTA is a sensitive and specific imaging modality for those patients who require further diagnostic evaluation.

PATIENTS AND METHODS

After institutional review board approval, all patients who sustained penetrating neck trauma presenting to the Los Angeles County + University of Southern California Medical Center and the R Adams Cowley Shock Trauma Center, two Level I trauma centers, between January 1, 2009 and July 31, 2011 (31 months) were prospectively screened for inclusion in this study. The inclusion criteria for enrollment were as follows: (1) age 16 years and older, (2) penetrating injury mechanism (gunshot wound [GSW], shotgun, or SW), (3) injury site bounded above by the inferior border of the mandible and occipital bone and below by the suprasternal notch anteriorly and the seventh cervical vertebra posteriorly.

During the study period, all patients meeting inclusion criteria were evaluated by an in-house attending trauma surgeon and managed according to the study algorithm. Patients underwent a structured clinical examination and were categorized as having "hard signs," "soft signs," or "no signs" of vascular or aerodigestive injury. Hard signs included active hemorrhage, expanding or pulsatile hematoma, bruit or thrill in the area of injury, shock unresponsive to initial fluid resuscitation, massive hemoptysis or hematemesis, and air bubbling through the injury site. These patients underwent immediate surgical exploration. Patients with no signs of neck injury other than the SW or GSW and who were completely asymptomatic underwent observation for a minimum of 24 hours before hospital discharge.

All other patients were considered to have soft signs of neck injury. These signs included venous oozing, nonexpanding, or nonpulsatile hematomas, minor hemoptysis, dysphonia, dysphagia, and subcutaneous emphysema. These patients underwent initial evaluation with MDCTA (Toshiba Aquilion 64 CFX multislice CT scanner, Toshiba Medical Systems Corporation, Japan [Los Angeles County + University of Southern California Medical Center] and Toshiba Aquilion 40 and 64 CFX multislice CT scanner, Toshiba Medical Systems Corporation, Japan [Shock Trauma Center]). The protocol is described in Appendix. Reconstruction was performed by an attending radiologist or interventional radiology fellow and the final attending read was used for the analysis.

Admission data collected included the following: age, gender, injury mechanism, systolic blood pressure, Glasgow Coma Scale score, and location of external wound. Findings from the structured physical examination performed at admission were documented for each patient. All patients included in the study were followed throughout their hospital stay. All operative procedures and the results of imaging were documented. Injury Severity Score (ISS), hospital length of stay, intensive care unit length of stay, and mortality were recorded.

Continuous variables were dichotomized using the following clinically relevant cut-points: age (55 years or older vs. 55 years and younger), systolic blood pressure at admission ($<$90 mm Hg vs. $\geq$90 mm Hg), Glasgow Coma Scale score at admission ($\leq$8 vs. $>$8) and ISS ($\geq$16 vs. $<$16).

The MDCTA sensitivity and specificity were tested against an aggregate gold standard of the final diagnosis at discharge which included operative exploration, catheter-based angiography, bronchoscopy, esophagogram and esophagoscopy results, and clinical follow-up. Descriptive statistics were applied. Values are reported as means $\pm$ standard deviation; median (range) for continuous variables, and as percentage for categorical variables. All analyses were performed using the statistical package for social sciences (SPSS Mac), version 18.0 (SPSS, Chicago, IL).

RESULTS

During the 31-month study period, 453 (1.7% total trauma admissions) patients were prospectively identified as having sustained penetrating neck trauma. Of these, 39 (8.6%) had hard signs of vascular or aerodigestive tract injury and underwent immediate surgical exploration (Fig. 1). Thirty-five (89.7%) were found to have 43 injuries intraoperatively. These included 14 external jugular, 8 internal jugular, 4 external carotid (ECA), 5 common carotid (CCA), 3 subclavian (SCA), 2 internal carotid (ICA), 2 vertebral (VA), 4 esophagus, and 1 trachea. A total of 6 patients (15.4%) had combined arterial and venous injuries. Despite having hard signs of injury, four patients (10.3%) had no evidence of vascular or aerodigestive tract injuries found intraoperatively. Three were taken to the OR for active bleeding. However, no named vessel or aerodigestive tract injury was found at operation. The fourth was in shock despite fluid resuscitation after an isolated chainsaw injury to the neck and was found to have significant disruption of the sternocleidomastoid and trapezius muscles with bleeding but no named vessel injury.

A total of 189 patients (41.7%) had no signs of vascular or aerodigestive tract injuries and were observed and discharged without a missed injury. Clinical follow-up was available for a mean of 2.6 days $\pm$ 1.1 days (median = 2

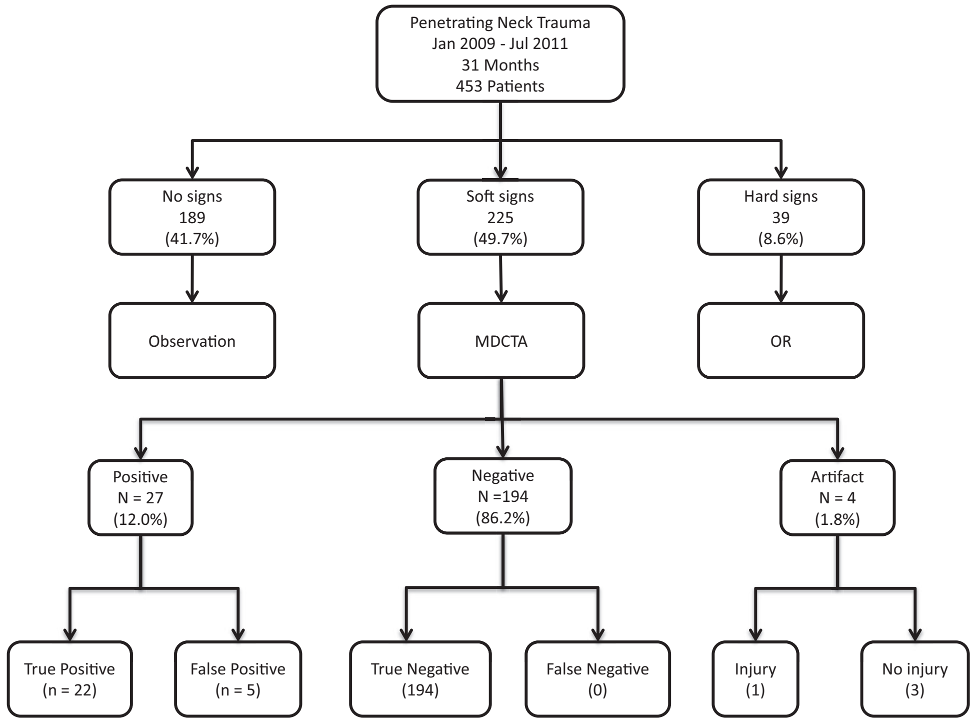

Figure 1. Study outline.

days; range, 1–58 days) with no delayed presentation of injury seen.

The remaining 225 patients (49.7%) underwent evaluation with MDCTA (Fig. 1). Of these, 186 (82.7%) had soft signs of injury and 39 (17.3%) were for proximity alone and not one of the preestablished soft signs of injury. These patients were asymptomatic but nevertheless underwent MDCTA at the attending surgeon's discretion for a trajectory in proximity to a vascular or aerodigestive structure. All MDCTAs performed for proximity alone were negative for injury.

The average age of the patients undergoing MDCTA was 31.3 years ± 12.7 years and 86.2% (194) were male. 61.3% (138) were SWs, 37.8% (85) were GSWs, and 0.9% (2) shotgun injuries. 16.9% (38) of external wounds were in zone I of the neck, 38.2% (86) in zone II, 16.0% (36) in zone III, and 28.9% (65) involved multiple zones. The mean ISS for this population was 9.1 ± 10.8 (Table 1). The most common soft sign was a nonexpanding or nonpulsatile hematoma (41.8%), followed by venous oozing (26.7%) and subcutaneous emphysema (4.9%; Fig. 2).

Overall, the sensitivity and specificity of MDCTA in detecting clinically significant vascular or aerodigestive injuries to the neck was 100% and 97.5%, respectively. There were a total of 28 injuries diagnosed in 22 patients (Table 2). There were 22 vascular injuries in 16 patients, 5 confirmed at angiography (1 VA, 2 ECA, 1 CCA, and 1 SCA) and 17 at operation (5 internal jugular, 2 external jugular, 2 ICA, 1 ECA, 1 SCA, and 6 CCA) (Table 2). There were six positive studies for aerodigestive tract injuries in six patients (3 esophageal and 3 tracheal) (Table 2). All tracheal and one of the esophageal injuries were repaired in the OR. For the remaining two esophageal injuries, one had confirmation of a small amount of contrast leak on esophagogram and was

TABLE 1. Demographic, Clinical Data, and Outcome for Patients Undergoing Evaluation With MDCTA

	n = 225
Age (y), mean ± SD; median (range)	31.3 ± 12.7; 27 (16–62)
Age ≥55 yr (%)	8.0 (18)
Male (%)	86.2 (194)
SW (%)	61.3 (138)
GSW (%)	37.8 (85)
Shotgun (%)	0.9 (2)
SBP on admission, mean ± SD; median (range)	131.9 ± 23.9; 132 (73–192)
SBP on admission <90 mm Hg (%)	2.2 (5)
GCS on admission, mean ± SD; median (range)	15 ± 2; 15 (3–15)
Neck zone 1 (%)	16.9 (38)
Neck zone 2 (%)	38.2 (86)
Neck zone 3 (%)	16.0 (36)
Neck multiple zones (%)	28.9 (65)
ISS, mean ± SD; median (range)	9.1 ± 10.8; 5 (1–35)
ISS ≥16 (%)	16.0 (36)
HLOS, mean ± SD; median (range)	5.5 ± 7.5; 3 (1–50)
ICU LOS, mean ± SD; median (range)	3.9 ± 7.4; 2 (1–50)
Mortality (%)	1.3 (3)

SD, standard deviation; SBP, systolic blood pressure; GCS, Glasgow Coma Scale; HLOS, hospital length of stay; ICU, intensive care unit.

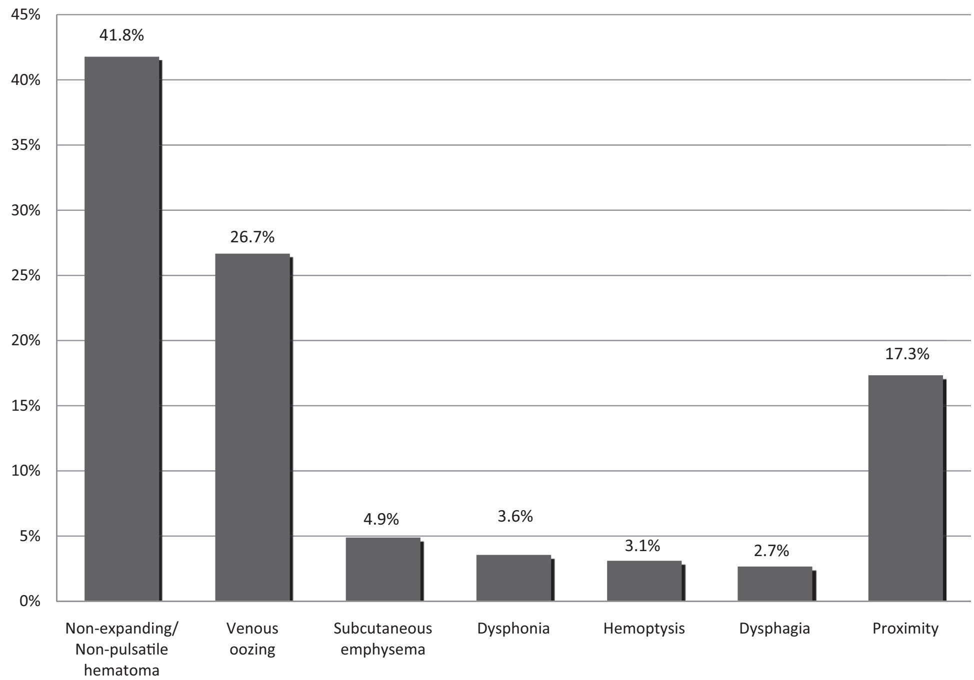

Figure 2. Description of the clinical indications for MDCTA.

successfully managed nonoperatively. For the second, the MDCTA was highly suspicious for an esophageal injury with a large amount of air tracking into the retropharyngeal space however an esophagogram could not demonstrate leakage of contrast. With close observation, 4 days later, a repeat CT demonstrated a retropharyngeal abscess and a repeat esophagogram demonstrated the injury. The patient was taken to the OR for surgical drainage of the area and the patient was successfully discharged home.

The specificity of MDCTA was 97.5%. Two patients (0.9%) had false-positive findings of vascular injury; one was read as a small ICA irregularity with air in the carotid sheath suspicious for injury. This was explored operatively and determined to be a false-positive finding. The second case was a SW with a subtle contour abnormality seen in the ICA that could not be ruled out as a pseudoaneurysm. This patient was brought to angiography which was negative. Three patients (1.3%) had air tracking that was highly suspicious for aerodigestive tract injury. Endoscopic evaluation and contrast swallow were used to rule out injury.

In total, 194 patients were negative for vascular or aerodigestive tract injuries. Clinical follow-up was available in these patients for a mean of 5.5 days ± 7.5 days (median = 3 days; range, 1–27 days). No missed injuries were detected in these patients.

MDCTA was nondiagnostic in four patients (1.8%) because of artifact from retained GSW missiles. Three patients were further evaluated with conventional angiography, bronchoscopy, and esophagogram, one of which was positive for a VA injury. One patient had no additional imaging and was observed for 4 days without vascular or aerodigestive complications.

DISCUSSION

Patients enrolled into this prospective protocol underwent a structured clinical examination by their attending surgeon. The neck was evaluated as a unit, with the physical examination being used to discriminate those patients at high risk of injuries from those at low risk that can be observed and those at intermediate risk who would potentially benefit from imaging. This was done by categorizing the hard signs, soft signs, and absence of signs of vascular or aerodigestive tract injury. The efficacy of this diagnostic algorithm was one of the primary outcome measures in this study. Patients who had hard signs of injury comprised less than 10% of those arriving with a penetrating neck injury. In these patients, the physical examination was highly specific with 89.7% having a clinically significant injury requiring intervention. For the 10.3% false-positive examinations who presented with active bleeding but on exploration had no named vessel injury, although technically classified as false positives, all had soft tissue bleeding that required extensive surgical wound care. Thus, for patients with hard signs, the high yield of injuries requiring repair warrants operative exploration.

For patients who arrive asymptomatic, it is highly unlikely that they will have a clinically significant injury, and imaging is not warranted. In this study, ~40% had no symptoms, and clinical observation was performed for a mean of 2.6 (range, 1–58) days with no missed injuries. Interestingly, of the 225 patients who did go to MDCTA, 17.3% of these were actually asymptomatic and did not benefit in this study from imaging. Nevertheless, at their attending surgeon's discretion they did and all had negative

TABLE 2. Injuries Identified in Patients Undergoing Evaluation With MDCTA

No.	Description	Mechanism	Zone	Treatment
Vascular injuries				
1	R CCA pseudoaneurysm	SW	2	OR
2	R IJV transection/extravasation, R ICA dissection	GSW	3	OR
3	L VA A-V fistula	SW	2	IR
4	R IJV transection/extravasation	SW	3	OR
5	L IJV transection/extravasation	SW	2	OR
6	L ECA transection/extravasation	SW	2	IR
7	Bil EJV transection/extravasation, R IJV transection, L ICA pseudoaneurysm	SW	3	OR
8	R ECA pseudoaneurysm	SW	3	IR
9	L CCA transection/extravasation	GSW	2	OR
10	L CCA extravasation; L SCA transection/extravasation	SW	1,2	OR
11	R IJV, EJV transection/extravasation	GSW	2	OR
12	R CCA transection/extravasation	GSW	2	OR
13	R CCA pseudoaneurysm	SW	2	OR
14	R CCA transection/extravasation	GSW	1,2	OR
15	R ECA transection/extravasation	SW	1,2	OR
16	R SCA transection/extravasation, R CCA pseudoaneurysm	GSW	1	IR
Aerodigestive injuries				
1	Esophagus	GSW	1	Observation
2	Esophagus	GSW	2	OR
3	Esophagus	GSW	2	Observation
4	Trachea	SW	2	OR
5	Trachea	SW	2	OR
6	Trachea	GSW	3	OR

Bil, bilateral; L, left; R, right; SW, stab wound; GSW, gunshot wound; ICA, internal carotid artery; VA, vertebral artery; IJV, internal jugular vein; EJV, external jugular vein; A-V, arteriovenous.

MDCTA studies, reinforcing the ability of physical examination to effectively rule out injury.

All the remaining 225 patients with soft signs underwent MDCTA. The role of MDCTA has been evaluated by Munera et al.[15,16] in a series of studies from 2000 to 2002 assessing the ability of MDCTA to detect arterial injury. He found a sensitivity ranging from 90% to 100%, specificity of 98.6% to 100%, positive predictive value of 92.8% to 100%, and negative predictive value of 98% to 100% using conventional angiography or operative exploration as the gold standard. As an initial screening examination for vascular and aerodigestive tract injuries, in the 2001 retrospective analysis by Gracias et al.[17] and the prospective analysis by Mazolewshi et al.[18] with 23 and 14 patients respectively, the latter with only zone II injuries, the authors concluded that CT was effective in limiting the number of invasive imaging tests used in patients sustaining penetrating neck injury. In 2003, Gonzalez et al.[19] prospectively evaluated computed tomography angiography in 42 patients with a zone II injury and no evidence of injury on physical examination. In their analysis, a unique patient population was captured with no carotid or laryngotracheal injuries but a very high rate of esophageal injuries, significantly different from the published literature. Four of these esophageal injuries were missed by physical examination, two of which were missed by both CT and esophagogram. At operative exploration, the authors describe the injuries missed by physical examination, CT, and esophagogram as minimal injuries, <0.5 mm, that likely may have healed without operative intervention. If clinically significant injures only were evaluated, their calculated sensitivity would have been 100%.

In 2006, a prospective analysis from the Ryder Trauma Center[20] was published, examining the role of MDCTA for the screening evaluation of both vascular and aerodigestive tract injuries. In this study of 91 patients, all patients with hard signs of injury went directly to the OR. All other patients however, including not only those with soft signs of injury but also those with no signs of injury underwent MDCTA evaluation. Using this protocol, a sensitivity of 100% and a specificity of 93.5% was reported. Our current study protocol has streamlined the evaluation process and assessed the utility of simply observing asymptomatic patients without MDCTA. By doing this, our sensitivity has remained at 100% with a specificity of 97.5%. With respect to the false-positive findings, in the Ryder study, the majority of the false-positive studies were because of the incorrect diagnosis of aerodigestive tract injuries. In this study, again, the most common false-positive read was of an aerodigestive tract injury. In this study, however, two cases of arterial false-positive injuries were also noted which were not seen in the Miami study. The reason behind this is not clear, however, the current generation CT scanners being used were 40 and 64 channel technology when compared with four in the Miami study and this, when combined with a different protocol and greater experience with interpretation, may have resulted in the misinterpretation of normal wall contour irregularities that are clinically insignificant and were not visualized on earlier generation CT scanners. Artifact also remains a problem regardless of the generation of CT being used. In our series, 1.8% had retained missiles and thus if suspicion for injury is high, from our analysis, confirmatory testing is recommended.

This study was the largest prospective study to date, performed at two high-volume trauma centers evaluating a clinical protocol for the work-up of penetrating neck injury and the role of MDCTA as a screening examination. Its primary limitation is that the clinical observation period was limited in some patients to 24 hours, and it is conceivable that patients were discharged home with a clinically significant injury and returned to a different facility for care, degrading the calculated sensitivity of 100%. Although this is unlikely as this is the primary treatment center for the demographic sampled by this study, the potential does exist. In addition, when designing the study, an aggregate gold standard was chosen rather than using mandatory conventional angiography, swallow and endoscopy ± surgery. Although all of our positive studies were verified, the negative studies were not. Although performing all these tests would have been ideal, with the available evidence attesting to the near perfect sensitivity of MDCTA, justifying the cost, time, risk, and radiation burden was not possible.

Although the largest study to date, as both esophageal and aerodigestive tract injuries[25–27] are relatively rare, accumulating sufficient numbers of these injuries prospectively remains a limitation. Finally, as has been mentioned previously, although all these technological advances have resulted in ever increasing sensitivities, there is always the real risk that as this technology evolves, clinically insignificant injuries will be detected in increasing numbers. This will then bring into question the impact of increasing radiation burden and the need for further confirmatory testing or even unwarranted surgical procedures to evaluate minor injuries that are seen on CT but that are actually clinically insignificant. Therefore, continuous clinical study will be required to not simply test the ability of CT to detect ever smaller injuries but to ensure that this imaging is being used to detect those injuries that are clinically significant.

In summary, a protocol using the physical examination to triage patients into those with hard signs, soft signs, and no signs of vascular and aerodigestive tract injuries was highly effective at minimizing the need for invasive imaging and the rate of negative surgical exploration. For those patients presenting with hard signs, immediate surgical exploration is warranted. Those who are asymptomatic can be safely observed. Imaging for "trajectory" in asymptomatic patients will not have a high yield. For those patients with soft signs of injury, initial screening imaging with MDCTA is associated with a high sensitivity and thus those with a negative MDCTA can be observed safely. As artifact from retained missiles remain a significant problem and can mask clinically significant injury, those with an equivocal MDCTA because of artifact should undergo evaluation with traditional catheter-based angiography, contrast swallow, and endoscopy.

CONCLUSION

In the initial evaluation of patients who have sustained penetrating neck trauma, physical examination can safely reduce unnecessary imaging. If imaging is required, MDCTA is a highly sensitive and specific screening modality for evaluating the vascular and aerodigestive structures in the neck.

AUTHORSHIP

K.I., B.C.B., and J.M. conceived of this study and conducted literature searches. K.I., B.C.B., J.M., T.S., J.D., S.R., and D.D. designed the study. K.I., B.C.B., J.M., S.C., and L.T. collected data, which were analyzed and interpreted by all authors. All authors participated in manuscript and figure preparation.

DISCLOSURE

The authors declare no conflicts of interest.

APPENDIX

The neck MDCTA protocol was standardized throughout the study period. The following parameters were used: 120 kVp, 100 mA to 250 mA (depending on size of patient, using dose modulation), gantry revolution speed of 0.5 second, beam pitch 0.656, beam collimation of 64 mm × 0.5 mm, variable field of view (depending on size of patient), and standard body kernel. Through a line suitable for power contrast injection, (18 or 20 gauge peripheral IV line in the antecubital fossa or a central venous catheter that has been approved by the manufacturer for power injection) 75 mL to 100 mL of iohexol iodinated IV contrast material (Omnipaque 350; GE Healthcare, Princeton, NJ) was injected at a rate of 4 mL/s to 5 mL/s followed by a 40-mL saline flush by a Medrad power injector (Spectris; Medrad, Indianola, PA). Contrast bolus tracking with a trigger threshold of 180 HU was used, with the region of interest placed in the carotid artery at the C2–3 level. Reconstruction with section thickness of 1 mm in the axial, coronal, and sagittal planes was performed, and additional postprocessing was performed by the radiologist on a Vitrea reformatting workstation (Vital Images, Plymouth, MN) to create volume renderings, maximum-intensity projections, and curved planar reformations as needed.

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DISCUSSION

Dr. Ronald Stewart (San Antonio, Texas): Thanks to the program committee for the honor of discussing this well written paper. I thank the authors for sending a well-written and concise manuscript well in advance of the meeting.

This work comes from two of the busiest trauma centers in North America. The authors propose a straightforward clinical protocol that can be followed at most trauma centers in the U.S.– Probably, many already use a variant of this evaluation scheme. The results are clearly and elegantly presented:

I believe their data speak for themselves. This technology is immediately available at most trauma centers in the US, and their protocol is commonsensical and easy to teach to surgeons. In short, I think this study definitively answers the question as to whether this approach is safe, effective and feasible.

I have only a few questions for clarity:

1. What about trauma centers that have older generation CT technology—specifically 16 slice and lower CT scans in their ED?
2. What was the clinical protocol for those observation patients with no signs or symptoms who did not undergo CT or OR? Were they observed a full 24 hours—in the ED, on the ward, was there a serial exam protocol? And did any of these patients cross over to get a CT scan or an operation?
3. It seems that "proximity" is a bit of a surgical "hedge" in the group of patients without symptoms or signs. You seem to discourage this in the discussion. Please comment, considering the vantage of trauma centers without the volume and experience that exist in your combined institutions.
4. Lastly, you had one esophageal injury that was managed successfully nonoperatively, but it sounds as if it was a missed injury by a confirmatory esophagogram after CT was suspicious for esophageal injury? Should we make the decision to operate based on either positive CT results or a positive esophagogram as it appears CT may be more definitive?

Congratulations again. This is an elegant and extremely useful study. Thanks again to the Program Committee and the authors.

Dr. Rao R. Ivatury (Richmond, Virginia): I enjoyed the paper and it seems that this is the state-of-the-art for penetrating neck injuries. I do have a concern about these esophageal injuries. We are not convinced that we can always pick them up in time, so my questions to you are: Did you solely rely on physical examination and CTA for diagnosis of esophageal injuries? Realistically, how many times did you go back and say, "let's go ahead and do an esophagogram?" So can you tell us the real truth? Thank you.

Dr. Charles E. Wiles III (Buffalo, New York): Congratulations, Jay, on a great paper. My question regards reconciling this with the Denver paper yesterday on expanding the criteria for screening for blunt cerebrovascular injuries. Did the ballistics of the wounding weapon have any impact on those you would choose to screen for proximity versus those that you would choose to continue clinical observation? Thank you.

Dr. Jay Menaker (Baltimore, Maryland): Thank you, Dr. Stewart, for your comments. I will try to answer all your questions.

The first question regarding 4- and 16-slice technology – unfortunately, this paper only looked at 40- and 64-slice technology so I'm not sure we can specifically answer that based on our information.

The question about patients being observed for 24 hours – all those patients were observed for 24 hours. They did have serial clinical exams. And none of those patients, at least in our study, required any further imaging or operative intervention.

The question about proximity – that is a real issue and sort of a surgical hedge. Our take was that it was better to over image these people as opposed to missing an injury in these people.

And your final question about the esophagogram and the missed injury – well, it looks like, at least in our data, that maybe the CTA does provide a better diagnostic tool for these patients than what would be the traditional considered gold standard.

Dr. Ivatury's question about evaluating the esophagus – in this specific study we used the CTA as the definitive test. We relied on the CTA for the diagnosis of an esophageal injury. Additional tests were at the discretion of the attending. For those patients that were observed, physical examination was the determining factor for imaging. However, we do realize that there is potential for a missed injury but none of our patients that we had follow up on had any clinically significant missed injury.

And Dr. Wiles' question about retained foreign body – the four patients in our study that did have a non-diagnostic CTA, was due to proximity and the obscuring as a result of retained ballistic fragments. I think these are patients that really do need to go on to further imaging.

The ballistics of the wounding weapon definitely had impact on our choosing to screen for injury. As I said earlier we do feel that over imaging in those patient populations is better than missing an injury.

Once again I'd like to thank the Association for the privilege of presenting our data.