CT Angiography of the Carotid Arteries in Trauma to the Neck


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Objectives: serious vascular injuries to the neck may be asymptomatic or masked by other life-threatening conditions. Angiography, the “gold standard” vascular imaging modality, is an invasive procedure. Moreover, it is time-consuming and thus may delay a needed vascular intervention. The results of screening angiography are negative in more than 80% of cases. Therefore other less invasive and faster screening tests, such as the Doppler ultrasound and magnetic resonance angiography, have been tested. This retrospective study was done to evaluate the use of CT angiography (CTA) in suspected vascular injuries of the neck.

Methods: from 1995 to 1998, 16 patients with suspected traumatic carotid artery injury underwent CTA. Twelve of these patients had penetrating injuries and four had blunt injuries to the neck. CTAs were obtained by Elscint Twin Flash Spiral Scanner, while MIP reconstructions were carried out on an Omnipro, Elscint (Indy, Silicon Graphics) work station and interpreted by a radiologist.

Results: all the CTAs were diagnostic. Positive findings included one complete tear of the right common carotid artery (confirmed by surgery) due to a penetrating injury and one bilateral internal carotid artery thrombosis after blunt injury to the neck. In addition, three patients with multiple trauma were operated on, due to either proximity only or questionable neurological findings. Surgical exploration confirmed the negative findings seen on CTA.

Conclusion: CT angiography of the carotid arteries in cervical trauma may be used as an accurate decisive tool for a needed surgical intervention. More studies with larger number of patients and comparison with angiography are needed.

Key Words: Carotid arteries; CT angiography (CTA); Cervical trauma.

Introduction

Traumatic cervical injuries, blunt or penetrating, may harm vital organs, which are compressed in a small space. Clinical diagnosis is difficult, and severe carotid artery injuries may be asymptomatic or masked by other life-threatening conditions. A delayed or missed diagnosis can be catastrophic, resulting in severe morbidity and mortality. The reported incidence of blunt injuries is very rare, comprising 0.08–0.4% of all blunt injuries.1,2

Management of penetrating cervical injuries has undergone many changes in the last 50 years and exploration in most cases is the accepted treatment today.3–5 The selection for non-surgical treatment is based on many diagnostic procedures, including chest and cervical spine X-rays, bronchoscopy, oesophagoscopy and angiography. The “gold standard” for carotid artery evaluation is conventional angiography.6–7 However, many studies with favourable results describing the use of CT angiography for carotid artery stenosis imaging have been published recently.8–12 Thus it is logical to evaluate this modality in trauma as well. This report presents our experience with CTA for carotid artery evaluation in cervical trauma in 16 patients.

Patients and Methods

From 1 January 1995 to 30 April 1998 a total of 9812 patients were referred to the emergency room for trauma (3250 patients per year), out of which 27 patients had suspected injury of the carotid artery. Sixteen patients were admitted to our Trauma Unit and referred for CT after stabilisation in the Emergency Room and evaluation by the attending vascular surgeon.

Patients with cervical trauma presenting with either expanding haematoma, bleeding or an associated neurological deficit (11 patients) underwent immediate surgery and thus were excluded from our study.
Scanning was performed by spiral CT, Elscint Twin Flash, with slice width of 2.7 or 3.0 mm, increments of 1.3 or 1.5, pitch of 0.7 or 1.0, from the base of the skull down to C6 level. The Twin Flash has a unique double helix system enabling scanning the region of interest in half the time compared to a single spiral scanner. The dual set of helical scanners rotated around the patient in a double, parallel, screw-like fashion. The higher speed accounted for minimal motion artifacts. We used 100–120 cc of low osmolar non-ionic contrast media, at an injection rate of 2.5–3.0 cc/s. Scanning began after a delay of 12 s. Acquisition time was 20–40 s, and reconstruction time for MIP images was 30–40 min. All the studies were reviewed by either a neuroradiologist or by an interventional radiologist. Problems with metallic artifacts in proximity to carotid arteries were dealt with oblique projections and adjustments of the appropriate CT window. In cases of a positive finding the patient was operated on, while those without carotid trauma according to CTA were not subjected to surgery unless there were other reasons. The results were confirmed by findings at neck exploration in four cases and compared with clinical information in 12 cases (for patients who were not operated on).

Results

Our patients were admitted within 2 h from the trauma except for one who was studied on readmission 1 week after discharge. Eight patients were unconscious and intubated during the CTA examination. The pertinent clinical information is demonstrated in Table 1. The male to female ratio was 15:1, and 14 out of 16 patients were under 30 years of age. The mechanism of injury was penetrating in 12 patients (75%) and blunt in four.

Associated cervical, non-vascular, findings included a laryngeal tear from shrapnel in patient no. 11, confirmed by neck exploration. Fracture of C6 (patient no. 2) and fracture of the C4 left ala with shrapnel in the spinal canal and normal carotid arteries was confirmed by neck exploration in patient no. 13 (Fig. 1). Air was found in the posterior and lateral compartments in patients nos. 4, 5, 6, 11, 14, 15 and 16. Large oedema of the soft tissues were found in patients 4, 5, 6. In addition, there were multiple associated non-cervical injuries such as: skull fracture (patient no. 1), pneumo- and haemothorax with or without lung contusion, ruptured spleen and multiple shrapnel wounds with or without fractures in the extremities.

CTA illustrated normal carotid arteries in 14 patients (11 with penetrating injuries and three with blunt injuries). Abnormal carotid arteries were seen in two patients. A complete tear of the right common carotid was demonstrated in a 16-year-old male (patient no. 1) injured by an explosion (Figs 2, 3). Immediate exploration confirmed the diagnosis and a primary end to end anastomosis was performed. Other associated injuries included skull fracture, infarction of the right middle cerebral artery area, and oesophageal perforation. After surgery the patient was admitted to the intensive care unit and was discharged, after 40 days, with left hemiparesis.

A bilateral internal carotid artery thrombosis was demonstrated in a 20-year-old male (patient no. 10) suffering from blunt trauma after a collision with a train (Fig. 4), who was re-admitted 1 week after discharge with acute psychosis. The suggested mechanism is bilateral internal carotid dissection caused by severe hyperextension and complicated by thrombosis and cerebral infarction.12,13,14 Conservative treatment with anticoagulation resulted in complete recovery after 1 month, except for a slight impairment in higher mental functions.

Three negative findings were confirmed by cervical exploration for non-vascular injuries. A 19-year-old patient (patient no. 16), with multiple injuries had a penetrating shrapnel cervical injury. Although, CTA findings were negative aside from proximity (Fig. 5), he underwent cervical exploration due to questionable neurological changes as stated by the primary physician. The carotid artery was intact, thus confirming the negative findings by CTA.

Patient no. 11 was operated on for a laryngeal tear during which the carotid artery was intact, as previously demonstrated by CTA. Patient no. 13, present as with tetraparesis, had a fracture of the C4 left ala with shrapnel in the spinal canal (Fig. 1). The follow-up period lasted from 1 day (in patient no. 6) to more than 2 years (in patient no. 9). The average follow-up period was 95 days for blunt injuries and 147 days for penetrating injuries. There were no late vascular complications, nor new neurological findings. During the long follow-up period four CTAs were obtained, one as a vascular follow-up after blunt carotid artery thrombosis showing improvement and three others as part of chest or brain scans reconfirming the negative results.

Discussion

Serious injuries resulting from penetrating neck trauma may be clinically asymptomatic,3,4 or masked
Table 1. Summary of cases.

<table>
<thead>
<tr>
<th>Pt No.</th>
<th>Age/ Sex</th>
<th>Cause of trauma</th>
<th>Clinical presentation</th>
<th>Other injuries</th>
<th>CT angio vascular findings</th>
<th>Follow-up</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16/M</td>
<td>Booby trap</td>
<td>Coma</td>
<td>Skull#, Extremities, Lung</td>
<td>Complete occlusion RCCA</td>
<td>2 years</td>
<td>Hemiparesis</td>
</tr>
<tr>
<td>2</td>
<td>26/M</td>
<td>Booby trap</td>
<td>Coma</td>
<td>Brain, C6#</td>
<td>Normal</td>
<td>5 days</td>
<td>Normal</td>
</tr>
<tr>
<td>3</td>
<td>26/M</td>
<td>MVA – blunt</td>
<td>Coma</td>
<td>Brain, Lung, Spleen</td>
<td>Normal</td>
<td>3 days</td>
<td>Death</td>
</tr>
<tr>
<td>4</td>
<td>20/M</td>
<td>Landmine</td>
<td>Alert</td>
<td>Soft tissues</td>
<td>Normal</td>
<td>52 days</td>
<td>Normal</td>
</tr>
<tr>
<td>5</td>
<td>45/F</td>
<td>GSW</td>
<td>Alert</td>
<td>Soft tissues</td>
<td>Normal</td>
<td>1 year</td>
<td>Normal</td>
</tr>
<tr>
<td>6</td>
<td>20/M</td>
<td>Fall</td>
<td>Alert</td>
<td>Soft tissue</td>
<td>Normal</td>
<td>1 day</td>
<td>Normal</td>
</tr>
<tr>
<td>7</td>
<td>24/M</td>
<td>MVA – blunt</td>
<td>Coma</td>
<td>Skull, Lung, Extremities</td>
<td>Normal</td>
<td>9 months</td>
<td>Normal</td>
</tr>
<tr>
<td>8</td>
<td>38/M</td>
<td>GSW</td>
<td>Alert</td>
<td>Soft tissue, Spleen</td>
<td>Normal</td>
<td>36 days</td>
<td>Normal</td>
</tr>
<tr>
<td>9</td>
<td>17/M</td>
<td>MVA – blunt</td>
<td>Paraplegia</td>
<td>Soft tissues</td>
<td>Normal</td>
<td>10 days</td>
<td>Paraplegia</td>
</tr>
<tr>
<td>10</td>
<td>20/M</td>
<td>Train – blunt</td>
<td>Psychosis</td>
<td>Lung, Spleen, Liver</td>
<td>Bilateral dissection ICA</td>
<td>4 months</td>
<td>Mental function impairment</td>
</tr>
<tr>
<td>11</td>
<td>20/M</td>
<td>Booby trap</td>
<td>Alert</td>
<td>Larynxg, Lungs</td>
<td>Normal</td>
<td>50 days</td>
<td>Normal</td>
</tr>
<tr>
<td>12</td>
<td>18/M</td>
<td>Boat</td>
<td>Coma</td>
<td>Lungs, Extremities</td>
<td>Normal</td>
<td>75 days</td>
<td>Disabled</td>
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<tr>
<td>13</td>
<td>22/M</td>
<td>Booby trap</td>
<td>Coma, tetraparesis</td>
<td>Soft tissues, C4#</td>
<td>Normal</td>
<td>3 weeks</td>
<td>Tetraparesis</td>
</tr>
<tr>
<td>14</td>
<td>20/M</td>
<td>GSW</td>
<td>Coma</td>
<td>Soft tissues</td>
<td>Normal</td>
<td>11 days</td>
<td>Normal</td>
</tr>
<tr>
<td>15</td>
<td>20/M</td>
<td>Landmine</td>
<td>Alert, paraplegia</td>
<td>Lungs, Spleen, Extremities</td>
<td>Normal</td>
<td>4 days</td>
<td>Paraplegia</td>
</tr>
<tr>
<td>16</td>
<td>19/M</td>
<td>Booby trap</td>
<td>Coma</td>
<td>Lungs, Extremities</td>
<td>Normal</td>
<td>10 days</td>
<td>Normal</td>
</tr>
</tbody>
</table>

MVA, motor vehicle accident; GSW, gunshot wound.

by coma and other life-threatening injuries. The leading cause of death in penetrating neck trauma is vascular injury. Patients with active bleeding, expanding haematoma or positive associated neurological findings are promptly operated upon. In stable patients most investigators suggest an integrated clinical and radiographic work-up, including bronchoscopy, oesophagoscopy, cervical spine and chest X-rays, and routine angiography to exclude vascular injury. The other option is cervical exploration...
for any injury penetrating the platysma. Results of screening angiography in penetrating injuries are negative in more than 80% of cases. Non-penetrating trauma with carotid injury is much less common, and a high index of suspicion is needed for early diagnosis. The cause can even be a minor trauma, such as in a sporting activity. The diagnosis is usually delayed, as occurred in patient no. 10, and screening angiography is not indicated. In both entities rapid diagnosis is required for successful intervention when required. Patients with penetrating injury have higher mortality rates (20–25% vs. 7–10%) but lower stroke rates (15–18% vs. 50–56%) than patients with blunt trauma.

Angiography, the “gold standard” for vascular injury, is costly, invasive and, above all a rather lengthy procedure. The delay required to stabilise and investigate multi-trauma patients may result in neurological irreversibility. Colour Doppler sonography and magnetic resonance angiography have been suggested as quicker and less invasive examinations for traumatic carotid artery injury. Spiral

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**Fig. 2.** For legend, see Figure 3 (below).
CT angiography of the Carotid Arteries

CT Angiography of the Carotid Arteries

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of carotid duplex. CTA is routinely performed, when needed, prior to carotid endarterectomy when complete occlusion is suspected or when duplex findings are not consistent with the patient's symptoms. This leaves arteriography for doubtful cases only.

In most trauma patients a brain, chest or abdominal CT is obtained anyway, and utilising the same modality for suspected carotid injury rather than moving the patient to MRI or invasive radiology facilities may further save time prior to the definitive operative treatment (if needed). In addition, cervical CTA may point out non-vascular (in the axial slices) pathologies that would not be picked up by angiography alone.

Colour Duplex has not gained widespread acceptance in trauma. The study may be technically difficult and demanding due to the nature of the injury. Open wounds, large haematomas, subcutaneous emphysema or even the pain resulting by touching the injured neck may hamper the accurate study result needed for treatment decision. In addition, ultrasonography is operator dependent and well trained careful operators are needed, especially in the setting of a polytrauma patient.

MRI is a good imaging modality for carotid arteries in stenoses and trauma. However, MRI is usually located outside the emergency area and in the setting of multiple trauma patients the transportation is not easy. Moreover, the accompanying resuscitation equipment might not fit in with the patient and the long narrow tube prevents sufficient monitoring of the patient. Also, various penetrating particles such as shrapnels may cause artifacts or even move during the study.

In our medical centre CTA is routinely performed, when needed, before carotid endarterectomy, leaving arteriography for doubtful cases only. Recently, several studies have presented numerous cases with carotid artery stenosis and a number of cases with carotid artery dissection in non-traumatic patients, demonstrated by CTA. These studies correlated well with conventional angiography. Our hypothesis was that CT angiography could replace routine conventional angiography as a screening test in trauma. This was also suggested by Nemzek et al. in 1996.

A recently published retrospective study compared the use of CTA to conventional angiogram for blunt cervical injury showing an earlier detection of injury with CTA. Moreover, a comparison between CTA and angiography in the diagnosis of penetrating trauma to the arteries of the neck demonstrated favourable results for CTA with 90% sensitivity, 100% specificity, 100% positive predictive value and 98% negative predictive value.

Fig. 4. Axial slice above the level of the common carotid artery bifurcation, showing a complete filling defect in the internal carotid arteries bilaterally (arrows) with intact vertebral and external carotid arteries.

Fig. 5. Axial slice, at the level of the third vertebral body, demonstrating air bubbles in the shrapnel's path in front of the neurovascular bundle. Small shrapnels (arrow heads) are located anteriorly to the intact left internal carotid artery. Note also fracture of the left mandible (arrow). The patient was uncooperative as seen by many motion artifacts.

CT angiography has been shown to compare well with conventional angiography in demonstrating non-traumatic carotid pathology.

Patients with severe carotid stenosis, in our medical centre, are generally operated on based on the results of carotid duplex. CTA is routinely performed, when needed, prior to carotid endarterectomy when complete occlusion is suspected or when duplex findings are not consistent with the patient's symptoms. This leaves arteriography for doubtful cases only.

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In our group of patients there were 12 cases of penetrating injury and four cases of blunt injury to the neck. None of the patients had clear signs of carotid injury (bleeding, expanding haematoma or related neurological signs). Most (91%) of the penetrating injuries occurred from high velocity injuries and the rest from stab wounds. Eight (50%) patients were unconscious during the examination, and seven (47%) patients required emergency surgical intervention for non-vascular indications. All had accompanying injuries in other organs. In addition, the majority of patients with penetrating injury had some type of metallic foreign bodies in the soft tissues, which limits the use of magnetic resonance imaging. All our examinations were conclusive, even those with a closely located metallic foreign body. Except for one case, all our patients required a CT examination for other reasons, so that obtaining a CTA added only a few more minutes to the evaluation. The Elscint CT-Twin Flash which was used has a two-fold shorter acquisition time compared to a single spiral scanner, thus decreasing motion artifacts. In addition, oblique projections and adjustment of the appropriate CT window were used to deal with shrapnel artifacts in proximity to the carotids.

A single-phase CT rather than three-phase CT was used in order to demonstrate a direct vascular injury if present. This scan is less time-consuming, while secondary signs of injury such as haematoma can be clearly seen by non-enhanced CT, although it is not a clear indication for surgery. A single scan for each patient was completely satisfactory to make a decision with confidence. Each scan consisted of approximately 200 axial slices. Axial slices were informative for both carotid and vertebral arteries. MIP reconstruction images were ready within 30–40 min, providing the surgeon a familiar (3D) anatomical view rather than running through 200 axial slices. The vertebral arteries were studied only in axial slices as it is impossible (time wise) to achieve a good MIP reconstruction due to close proximity to bony structures (vertebrae). This kind of reconstruction is not possible by computerised software and is done by hand on each and every axial slice.

A limitation of our study is that there is no correlation with conventional angiography. That is, the false negative call of CTA as compared to angiography for each patient is unknown. Nevertheless, a good correlation in the uninjured patient has been well demonstrated before and the fact that our studies in the injured patient were conclusive is favourable. Moreover, four patients underwent immediate neck exploration; one with a positive carotid injury by CTA and three with (negative) normal carotid arteries. In all these patients the intraoperative findings at surgery accurately matched the preoperative CTA diagnosis. Our follow-up is longer than that noted by Fabian et al. in 1990 and by Ramadan et al. in 1995 as it is possible to harbour complications. Since no clinical deterioration or complication occurred in patients with normal carotid arteries who were not operated on, even a possible false negative call by CTA would have been a minor one without a need for surgery.

CTA demonstrated the cervical vascular and non-vascular pathologies quickly and reliably, and our results indicate that CTA may be used for the evaluation of carotid arteries in trauma to the neck, especially in multi-trauma patients.

More studies including a larger number of patients, especially with a positive finding and comparison with angiography, are needed.

References


