Traumatic rupture of the innominate artery

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Abstract

Objective: Blunt traumatic rupture of the innominate artery is uncommon. We reviewed our experience to correlate the impact of patient stability, presence of associated injuries and location of the injury within the artery with outcome. Methods: A retrospective review was performed of patients admitted between January 1, 1998 and December 17, 2002 with traumatic innominate artery rupture. Injuries were defined as proximal if they were ≤0.5 cm from the origin, distal if ≤0.5 cm from the bifurcation and middle if in between. Results: Over the 5-year study period, 66 patients were admitted with aortic or great vessel injury, including eight with blunt innominate artery disruption. Of the blunt innominate injuries, six involved the origin (five repaired by ascending aortic–innominate artery graft followed by over-sewing of the injury site, one by ligation alone), one middle (treated by interposition graft) and one distal (managed with resection and primary anastomosis). Four of the patients with proximal injuries had evidence of active bleeding (large expanding hematoma and/or frank bleeding) requiring control of the injury site prior to reconstruction. All patients had associated injuries (including closed head injury in three and splenic rupture in two). The only mortality occurred in a patient who presented in shock, and suffered tracheal rupture and severe blunt cardiac injury requiring cardiopulmonary bypass. The remaining patients were stable on presentation. Diagnosis was suspected after chest X-ray demonstrated widened mediastinum and was confirmed with either angiography or computer tomography scan. There were no complications in the survivors. Neither cardiopulmonary bypass nor aorto-carotid shunting was utilized in these cases. Conclusions: Patients with blunt innominate artery rupture who survive to admission are usually stable and the diagnosis is suggested by initial chest radiograph. The injuries are usually proximal, requiring aortic–distal innominate bypass. Cardiopulmonary bypass is required only if there is evidence of heart failure (either before or after partial occlusion of the aorta) or to manage specific associated injuries.

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1. Introduction

Innominate artery rupture is associated with specific management concerns, in particular, the role of cardiopulmonary bypass and the need for shunting to maintain cerebral perfusion [1,2]. We reviewed our experience over a 5-year period to correlate both clinical presentation and injury anatomy with outcome.

2. Methods

A retrospective review of patients admitted to Harborview Medical Center between January 1, 1998 and December 17, 2002 was performed. Patients with blunt injuries to the innominate artery were identified and their course reviewed. Injuries were defined as proximal if they involved the vessel within 0.5 cm of the aorta, distal if within 0.5 cm of the bifurcation and middle if in between. These findings were confirmed by the operative report. Approval from the Institutional Review Board was obtained prior to starting data gathering.

3. Results

Over the study period, 65 patients were admitted with injuries to the thoracic aorta or intra-thoracic great arteries (Table 1). Eight patients underwent operative repair of blunt injuries to the innominate artery, all following motor vehicle crash (Table 2). All but one presented within 60 min of injury. This latter patient was transferred from an outlying institution 8 h after injury. The majority had significant
associated injuries and all but one presented with stable systolic blood pressures (> 90 mmHg). This solitary patient presented in shock with hemoptysis and a widened mediastinum on chest radiograph. Bronchoscopy confirmed rupture of the right mainstem bronchus and he underwent mediastinal exploration through a sternotomy. Massive hematoma involving the upper mediastinum was encountered, prompting control of the origin of the innominate artery. The artery was found to be completely disrupted just distal to its origin off the aorta. Because of ongoing cardiogenic shock and inability to ventilate, cardiopulmonary bypass was initiated and the right main-stem bronchus was repaired through a trans-pericardial approach. After weaning from bypass, the patient promptly went into cardiogenic shock which necessitated the insertion of an intra-aortic balloon pump. Despite our efforts, the patient experienced repeated cardiac arrests which ultimately led to his demise. This was the only mortality.

The remaining patients were diagnosed prior to operation, and all had pseudoaneurysms. Although associated injuries were common (Table 2) all were stable on presentation. None of the patients with closed head injury manifested focal neurological findings. All patients had equal blood pressures bilaterally. Two patients had a clear ‘shoulder-belt’ sign extending from the base of the neck on the right side across the precordium, which suggested injury to the intra-thoracic or right carotid vessels (Fig. 1). In one case, widened mediastinum on chest radiography led directly to angiogram (Fig. 2); in two instances, a chest computed tomography (CT) was performed demonstrating hematoma predominantly in the region of the ascending aorta and arch prompting aortography; helical CT angiogram provided the diagnosis in two cases. In two cases helical CT angiogram demonstrated extensive hematoma along the arch and around the great vessels, but did not demonstrate pseudoaneurysms (although in the last case a dissection of the innominate artery was demonstrated). Angiograms were obtained that demonstrated pseudoaneurysms, in the last case involving both the root of the innominate artery as well as the base of the left common carotid artery. In four cases, the origin was involved and upon exposure, active hemorrhage necessitated control with pledgeted sutures followed by insertion of an end-to-end graft originating from the ascending aorta. These patients had large hematomas on sternotomy suggesting active bleeding, which prompted proximal control as the initial maneuver. In all cases sternotomy with small ‘carotid’ extensions provided exposure for the innominate and proximal subclavian and carotid arteries. Aortic–carotid shunting was not employed in any case. Stump pressures were measured in the last three cases and were ≥ 40 mmHg. In the one case of distal injury that required temporary occlusion of the subclavian and common carotid vessels,

Table 1
Incidence of injuries

<table>
<thead>
<tr>
<th>Blunt thoracic aorta (48)</th>
<th>Ascending (3)</th>
<th>Arch (3)</th>
<th>‘Isthmus’ (40)</th>
<th>Supra-diaphragmatic (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common carotid artery (3)</td>
<td>Gunshot wound (1)</td>
<td>Stab wound (1)</td>
<td>Blunt (1)</td>
<td></td>
</tr>
<tr>
<td>Left subclavian artery (5)</td>
<td>Gunshot (3)</td>
<td>Blunt (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Innominate artery (10)</td>
<td>Gunshot (2)</td>
<td>Blunt (8)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2
Patient characteristics and outcomea

<table>
<thead>
<tr>
<th>Age, gender</th>
<th>Associated injuries</th>
<th>Diagnosis</th>
<th>Location</th>
<th>Treatment</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>33, Male</td>
<td>CHI</td>
<td>Agram</td>
<td>Origin</td>
<td>Ascending aortic–innominate graft end–end</td>
<td>Lived</td>
</tr>
<tr>
<td>18, Female</td>
<td>Sternal fracture</td>
<td>Agram after CT</td>
<td>Bifurcation</td>
<td>Primary</td>
<td>Lived</td>
</tr>
<tr>
<td>35, Male</td>
<td>Rib fractures</td>
<td>Agram after CT</td>
<td>Origin</td>
<td>Ascending aortic–innominate graft end–end</td>
<td>Lived</td>
</tr>
<tr>
<td>20, Male</td>
<td>CHI, blunt cardiac injury, carinal rupture, splenic rupture, pelvic fracture</td>
<td>Clinical</td>
<td>Origin</td>
<td>Graft end–end</td>
<td>Died in OR</td>
</tr>
<tr>
<td>45, Male</td>
<td>CHI, pelvic fracture, splenic rupture</td>
<td>CTA</td>
<td>Origin</td>
<td>Ascending aortic–innominate graft end–end</td>
<td>Lived</td>
</tr>
<tr>
<td>63, Female</td>
<td>Retro-sternal dislocation of clavicle</td>
<td>CTA</td>
<td>Mid</td>
<td>Interposition graft end–end</td>
<td>Lived</td>
</tr>
<tr>
<td>78, Male</td>
<td>C2 distraction injury (cord intact), myocardial contusion</td>
<td>Agram after CT</td>
<td>Origin</td>
<td>Ascending aortic–innominate graft end–end</td>
<td>Lived</td>
</tr>
<tr>
<td>21, Male</td>
<td>Tear at origin left common carotid</td>
<td>CTA&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Origin</td>
<td>Ascending aortic–innominate graft end–end</td>
<td>Lived</td>
</tr>
</tbody>
</table>

<sup>a</sup> CHI, closed head injury; CTA, computer tomographic angiogram; CT, computer tomography; Agram, angiogram.

<sup>b</sup> CTA demonstrated dissection, but Agram noted associated tear of ascending aorta proximal to the origin of innominate artery as well as tear at base of left common carotid.
there was evidence of vigorous back bleeding. All patients recovered without neurological deficit.

**4. Discussion**

Blunt rupture of the innominate artery is uncommon in patients admitted following chest injury, although it represents the second most common thoracic vascular injury after aortic disruption [3]. The mechanism has been postulated to represent traction on the artery (Fig. 3) [1,4,5]. Penetrating injury is a more common cause [2,6,7]. Chen and associates noted that of 166 patients who underwent angiography for traumatic vascular injuries, four had

Fig. 1. ‘Seat-belt sign’ reproduced with permission from Nicholls [11].

Fig. 2. Angiogram demonstrating tear in proximal portion of innominate artery. At surgery the superior extent of injury was found to involve the junction of the innominate with the aorta.
innominate artery rupture [8]. It is possible that the majority of patients who suffer blunt disruption of the innominate artery die at the scene or during transport to the hospital [1,9].

The majority of patients who do present for evaluation are stable, although they often have associated injuries [10]. The most common injuries are rib fractures (46%) followed by pneumothorax (36%) [10]. The diagnosis is suggested by clinical exam (bruit, supraclavicular hematoma, pulse deficit). A shoulder-belt sign can also suggest the diagnosis. This is a vivid bruise following the pattern of the restraining belt running from the base of the right neck and across the chest, and was noted in two (25%) of our cases [10]. In our series, the primary reason that the diagnosis was suggested was by a widened mediastinum on chest radiography [1,4]. ‘Standard’ CT is insufficient to rule out injury. Helical CT angiogram, if it demonstrates a pseudoaneurysm, is sufficient to make the diagnosis and may provide enough information (particularly after three-dimensional reconstruction) to permit operation without requiring angiography. However, based on our experience (particularly with the two most contemporary cases), we feel that if CT or CT angiogram demonstrates hematoma surrounding the ascending, arch and or great vessels without demonstrating a pseudoaneurysm (which would be consistent with this as opposed to a simple dissection), then arteriography is required. In particular, CT scans do not appear to reliably define the anatomy of injury occurring at the origin of the innominate artery. Thus, in the majority of cases, angiography will be required.

Patients with simple dissection without extensive surrounding hematoma, may be managed non-operatively as long as cerebral duplex studies do not show evidence of embolic phenomenon [11]. However, we believe that patients with pseudoaneurysm should be treated as urgent cases because of the risk of rupture. As previously discussed, the majority of force appears to be directed at the root of the artery, thus most innominate artery injuries are located at or very close to the origin [8,9]. Median sternotomy is the approach of choice in both controlling hemorrhage and repairing the arterial injury. Repair is accomplished by running a graft from the ascending aorta to the innominate artery and is anastomosed end-to-end fashion. The proximal injury can then be controlled with pledgeted sutures [2]. Injuries to the middle region of the innominate artery can be repaired with an interpositional graft in order to restore antegrade flow to both the common
carotid artery and the subclavian artery [10]. Occasionally, more distal injuries require Y-grafts [6]. Resection and primary anastomosis can be performed for injuries not associated with extensive tissue loss or tension [1]. Cardiopulmonary bypass is rarely required unless there is evidence of heart failure (cardiac distension, low output and/or arrhythmias), when partial clamping of the ascending aorta is performed to manage specific associated injuries (such as cardiac valve rupture or associated airway lesions that prevent oxygenation) [1,12,13].

In some cases, pre-operative angiogram may demonstrate an adequate collateral supply via the Circle of Willis and this can reduce concern regarding the need for aortic–carotid shunting [4]. Most authors have found shunting to be unnecessary. Since most injuries are proximal and the distal clamp is placed proximal to the innominate bifurcation, retrograde flow from the contralateral vertebral artery allows for ipsilateral carotid perfusion [2,14]. This can be confirmed by demonstrating vigorous back bleeding or measuring stump pressures. The method of choice has evolved into performing an ascending aortic (end-to-side) to distal innominate (end-to-end) graft followed by closure of the proximal injury [2,9]. This allows reduced clamp time. However, we noted in some cases that active bleeding may necessitate control of the injury first. If a patient has extensive aortic calcification, this may not be possible and other options, including possibly hypothermic circulatory arrest, may be required [15].

When operating for distal tracheal rupture and great vessel injury is suspected, sternotomy provides the most versatile approach. The tracheo-bronchial tree can be approached between the superior vena cava and ascending aorta, incising the pericardium and reflecting the right main pulmonary artery [16]. If the specific site of great vessel injury is not identified, or a large hematoma is encountered, proximal control of the great vessels is best obtained by opening the pericardium (thus staying out of the hematoma) and dissecting along the curvature of the aorta [17].

The mortality and procedure related complication rate of patients who undergo operation for blunt innominate rupture can be as high as 30 and 40%, respectively [2]. The overall complication rate has been 100% in some series, but the bulk of these are due to associated injuries [1,2]. Patients who present with CNS injuries have the worse prognosis [2].

In stable patients, there has been interest in using endovascular stent graft approaches to manage these injuries. This requires that the injury is relatively central. We have found that grafts are best deployed via the right common carotid artery as this allows a direct approach to the innominate artery [11,18,19]. We have used this approach to manage a patient (not included in this series) who presented with thrombosis of an ascending aortic (end-to-side) to innominate (end-to-side) graft in whom the proximal artery had been simply ligated. This resulted in thrombosis extending into the graft. Using an endovascular approach after thrombectomy cleared the graft of clot, a non-covered expandable stent was used to maintain graft patency. It may be that in patients with significant comorbidities that preclude operation, but with large injuries that suggest that non-operative treatment is prohibitively risky, that covered stent grafts may be an option even though the anatomy requires the graft to be placed across the origin into the aorta or into the right common carotid thus occluding the subclavian, or both.

5. Conclusion

Patients admitted with blunt traumatic rupture of the innominate artery are usually stable. The diagnosis is most often made by recognizing mediastinal widening on initial chest radiograph, prompting further evaluation. Angiography remains the gold standard, but increasing experience with helical CT angiography may allow this to become an acceptable diagnostic alternative, if positive for pseudoaneurysm. In the setting of hematoma surrounding the great vessels or their origin, a ‘negative’ CT angiogram, or one that shows only a dissection, requires subsequent angiography. The majority of innominate artery injuries are proximal and they are surgically managed with ascending aortic-to-end innominate artery bypass grafts. In most instances, this requires neither cardiopulmonary bypass nor aortic—carotid shunting.

References