The Role of Clinical Examination in Excluding Vascular Injury in Haemodynamically Stable Patients with Gunshot Wounds to the Neck. A Prospective Study of 59 Patients

G.S. Mohammed,* W.R. Pillay, P. Barker and J.V. Robbs

Department of Surgery, University of Natal, Durban, South Africa

Objective. To prospectively evaluate the safety and accuracy of physical examination in determining the management of stable patients with gunshot wounds to the neck.

Design. Prospective study of 59 patients with gunshot wounds to the neck.

Patients and methods. Fifty-nine stable patients with gunshot wounds to the neck managed between December 2001 and August 2003. All patients had a physical examination and routine angiography according to a written protocol approved by the research ethics committee. The sensitivity, specificity, and predictive values of physical examination were assessed and compared with the angiographic findings.

Results. Thirteen patients with positive findings on physical examination (history of bleeding, haematoma, minimal bleeding, thrill, bruit and pulse deficit) and 10 patients without clinical signs of vascular injury had vascular injury. A sensitivity of 57%, specificity 53%, positive predictive value 43% and negative predictive value of 67% were calculated for physical examination alone in detecting vascular injury.

Conclusion. Findings on physical examination are not good predictors of vascular injury in stable patients with gunshot wounds to the neck. Our findings question the validity of physical examination alone, as a safe and accurate assessment of patients with gunshot wounds to the neck. Arteriography or ultrasonography is needed to identify vascular injuries.

Keywords: Gunshot neck; Physical examination; Angiography.

Introduction

The increased use of firearms in civilian violence in South Africa during the last two decades has caused a dramatic increase in the number of patients presenting with gunshot wounds to the neck. Few articles addressing penetrating injuries distinguish between stab and gunshot wounds. The latter can cause more damage, with minimal clinical signs.1

Optimal management of patients with vascular injury after penetrating neck trauma remains controversial. Retrospective studies have demonstrated that physical examination alone may be as accurate as angiography in detecting significant cervical vascular injuries requiring operative repair.23 However these studies do not differentiate between stab and gunshot injuries.

As far as we can ascertain there is no published prospective study that specifically addresses gunshot wounds in the English literature, which prompted the present study.

Patients and Methods

A prospective study was performed at the Nelson R Mandela School of Medicine of the University of Natal at the following hospitals: King Edward VIII Hospital, Addington Hospital and the R K Khan Hospital. These hospitals are served by a single metropolitan vascular unit. This is a busy vascular unit in an area with a high rate of penetrating wounds to the neck. The unit receives referrals from all over the province of KwaZulu-Natal. This study was approved by the Ethics Committee of the University of Natal. Informed consent was obtained from patients for enrolment in the study. The study period was 16 months, up to August 2003. Of the 59 patients enrolled in the study, 56 were of African descent, two of Asian, and one Caucasian. These patients ranged in age from 13 to 70 years, with a mean of 27 years. All haemodynamically stable...
stable patients who had sustained a low velocity gunshot wound to the neck were included. All patients with unstable conditions such as active bleeding, expanding haematomas causing airway compression, and patients with obvious tracheal injury were excluded, and were subjected to immediate exploration.

All the study patients underwent a clinical examination according to a written protocol and all were subjected to arch and four-vessel angiography. A water-soluble contrast swallow was performed when perforation of the oesophagus was suspected. Chest X-rays were obtained in all patients and cervical spine X-rays were obtained when indicated (suspected cord injury or absent exit wound). All percentages in this study were brought to the nearest whole number.

Results

The overall mean interval between injury and presentation to hospital was 14 h and 32 min. Analysis of the data defined two patient groups, based upon the angiographic findings: 36 patients (61%) in group A (normal angiographic findings), and 23 patients (39%) in group B (abnormal angiographic findings). The abnormal angiographic findings ranged from an intimal tear with or without thrombosis to a small false aneurysm and arterio-venous fistula. One angiogram in this series demonstrated thrombosis of the internal jugular vein.

The most common site of the entry wound was in Zone II (the mid-neck from clavicle to the inferior margin of mandible, as described by Saletta et al.) noted in 26 (44%) patients, 11 of whom had a vascular injury. Seventeen (29%) patients had Zone I (the area of the base of the neck) injury, and eight were situated in Zone III (extending from lower border of mandible to the base of skull). In eight patients the entry wound was situated outside borders of the neck (face, chest, or shoulders). In two patients there was more than one entry wound. In terms of the triangles of the neck most wounds were in the anterior triangle (48 patients).

The estimated trajectory of the missile, adjudged by the sitting of the exit wound, or the position of a retained missile is shown in (Table 1) findings suggested that if the path is towards the midline or the clavicle, the chance of a vascular injury is greater.

The blood vessels involved are shown in (Table 2). Twenty-three patients had 27 vascular injuries. The commonest vessel involved was the common carotid. Three patients had combined common carotid and vertebral artery disruption. Of the 29 patients without signs, 10 had evidence of vascular injury on angiography. Of 30 patients with signs of vascular injury only 13 were confirmed on angiography. When angiography was taken as the gold standard in the total of 59 patients the overall sensitivity of physical examination was 57%, specificity 53% positive predictive value 43% and negative predictive value 66%.

Table 3 shows the value of specific clinical signs in more detail. The data suggest, that bruit, palpable thrill or pulse deficit are the most significant signs in this context. Although the number are small.

Associated injuries found in this study were: (i) Seven brachial plexus injuries, four of which were associated with arterial injuries. (ii) Three cervical spine fractures with paraplegia, two of which were associated with vascular injuries. (iii) Quadriplegia was noted in three patients, two of whom had no obvious cervical spine fractures, while one had contusion of the lamina at the level of C5, and narrowing of the spinal canal as seen on CT scan (percussion injury). (iv) Twenty-five patients had injuries to other structures: (including lung contusion, pneumothorax and fracture of the clavicle, ribs or maxilla, eye, tracheal and pharyngeal injury).

Eight of these patients had vascular injuries: 3 haemo-pneumothoraces, 2 mandibular fractures, 1 pharyngeal injury, 1 lung contusion and 1 eye injury.

Three patients had a central neurological deficit one monoplegia (internal carotid injury), 2 hemiplegia (common carotid injury).

An oesophagogram was performed on 43 patients, of whom four had contrast extravasation. Symptoms and signs suggestive of aero-digestive injury were found in three patients; two had surgical emphysema, and one had dysphagia. The latter was found to have contrast extravasation at the C4 level and an oesophageal laceration was found at surgery. The laceration was closed in two layers without drainage. This patient had an associated injury to the common carotid

Table 1. Path of the bullet

<table>
<thead>
<tr>
<th>Group A normal finding</th>
<th>Group B abnormal finding</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toward midline</td>
<td>6</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>Toward clavicle</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Away from midline</td>
<td>18</td>
<td>5</td>
<td>23</td>
</tr>
<tr>
<td>Crossing midline</td>
<td>11</td>
<td>6</td>
<td>17</td>
</tr>
</tbody>
</table>

Eur J Vasc Endovasc Surg Vol 28, October 2004
artery. Arterial repair was undertaken at the same sitting. The other three patients had no vascular injuries and were treated conservatively without complications.

Chest X-rays were obtained in all cases. Cervical spine X-rays were obtained when indicated (cord injury or absent exit wound). Abnormalities were found in 10 (17%) patients on chest radiograph. The most common findings were haemo-pneumothoraces in seven patients (three in patients with a vascular injuries) and a widened mediastinum in one patient (who was found to have brachiocephalic and internal jugular vein injuries).

Overall results are summarised in (Fig. 1). Twenty-nine patients (49%) had no signs suggestive of vascular injury, while 30 patients (51%) had ‘soft’ signs (history of bleeding, non-pulsatile haematoma) or ‘hard’ signs (pulsatile haematoma, bruit, thrill, pulse deficit) of vascular injury. The most common abnormal clinical finding was a small, non-pulsatile haematoma in 25 patients (42%), followed by a pulse deficit in four patients (7%), minor bleeding in four patients (7%) and a bruit in two patients (3%).

### Management

Vascular interventions were undertaken in 16 patients, three patients had more than one arterial injury. Vascular repair was undertaken in 11 patients, six to the common carotid artery, one to the internal carotid artery, two to the subclavian artery, one to the axillary artery and one to the descending aorta. Ligation of the arteries was carried out on only four occasions. In two patients with internal carotid artery injuries, the injury in the distal part of the artery, very close to the base of the skull. Distal control was difficult to obtain, thus ligation was undertaken. Both patients did well post-operatively, although one developed a facial nerve palsy. The other two patients had vertebral artery injuries. One developed an ipsilateral pneumothorax managed successfully with closed tube thoracostomy. One patient with ligation of the vertebral artery also required common carotid artery repair. Four patients were managed by embolisation; one patient had ipsilateral embolisation of vertebral artery at the time of angiography. Another patient had a vertebral artery embolisation two days after an ipsilateral common carotid artery repair. A branch of the left maxillary artery was also successfully embolised. Embolisation failed in only one patient with vertebral artery injury. All the patients did well after the performed procedures. No shunts were used in carotid artery repair.

There were two patients with venous injuries; one patient had thrombosis of the internal jugular and left brachiocephalic veins, diagnosed by duplex prior to angiography, while the other had complete thrombosis of the internal jugular vein, confirmed by angiography. In most cases, the magnitude of the arterial vascular injury necessitated interposition vein or prosthetic grafts because of extensive injury. In five patients, arterial repair was by means of polytetrafluoroethylene (PTFE) prosthetic grafts. On two occasions, Silver Impregnated Dacron grafts were used. Autologous vein grafts were utilised in three cases and lateral suture following adequate vessel debridement was used in one case.

Seven patients with positive angiographic findings were observed. Three patients sustained common carotid injury, one internal carotid, one axillary artery and two venous injuries. One patient with common carotid artery injury refused surgery and despite anticoagulation therapy developed dense hemiplegia. The surgery in the other three patients was postponed due to deterioration of cerebral ischemia. The patient with axillary artery injury also had cord injuries and quadriplegia with a viable limb. Two patients with

### Table 2. Sites of vascular injuries

<table>
<thead>
<tr>
<th>Site</th>
<th>No. of injuries</th>
</tr>
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<tbody>
<tr>
<td>Arterial</td>
<td></td>
</tr>
<tr>
<td>Aorta</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Common carotid</td>
<td>8 (31%)</td>
</tr>
<tr>
<td>Internal carotid</td>
<td>4 (15%)</td>
</tr>
<tr>
<td>Vertebral</td>
<td>5 (19%)</td>
</tr>
<tr>
<td>Subclavian</td>
<td>2 (8%)</td>
</tr>
<tr>
<td>Axillary</td>
<td>2 (8%)</td>
</tr>
<tr>
<td>Maxillary branch vessel</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Venous</td>
<td></td>
</tr>
<tr>
<td>Brachiocephalic vein</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Internal jugular vein</td>
<td>2 (8%)</td>
</tr>
<tr>
<td>Total</td>
<td>26 (100%)</td>
</tr>
</tbody>
</table>

### Table 3. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of clinical vascular signs in 59 patients

<table>
<thead>
<tr>
<th>Clinical Signs</th>
<th>No. of patients</th>
<th>Sensitivity%</th>
<th>Specificity%</th>
<th>PPV%</th>
<th>NPV%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hematoma</td>
<td>25</td>
<td>39</td>
<td>56</td>
<td>36</td>
<td>59</td>
</tr>
<tr>
<td>Bleeding</td>
<td>4</td>
<td>13</td>
<td>97</td>
<td>75</td>
<td>64</td>
</tr>
<tr>
<td>Bruit</td>
<td>2</td>
<td>9</td>
<td>100</td>
<td>100</td>
<td>63</td>
</tr>
<tr>
<td>Thrill</td>
<td>1</td>
<td>4</td>
<td>100</td>
<td>100</td>
<td>62</td>
</tr>
<tr>
<td>Pulse deficit</td>
<td>4</td>
<td>18</td>
<td>100</td>
<td>100</td>
<td>66</td>
</tr>
</tbody>
</table>

Eur J Vasc Endovasc Surg Vol 28, October 2004
venous injuries remain stable and no intervention was required.

Of the 36 patients with normal angiographic findings, they were observed for 24 h, before being returned to their referring hospitals. None of these patients required late surgical intervention.

Discussion

Low velocity gunshot wounds, which differ in their mechanism of injury from other penetrating wounds, can cause a variety of vascular injuries. It is known that a bullet may not follow a straight path through the tissues, especially where kinetic energy is low. On occasion, vascular injury has been found to occur without apparent direct trauma to the vessels. Shockwave experiments on the femoral arteries of dogs have demonstrated significant damage to all layers of the arterial wall, with the potential for the development of thrombosis, embolism and false aneurysm. A 'percussion-percussion' effect may, momentarily, sufficiently displace and distort the arterial anatomy to produce an intimal fracture. The cavitation effect resultant on high velocity weapons, can cause more damage by dissipating a great deal of energy as the projectile passes through the tissues. Predicting vascular injury in gunshot wounds of the neck is very difficult because of the erratic trajectories of the missiles and their velocities. In addition, cavitation can cause tissue destruction well beyond the path of the missile.

The mechanism of injury with missiles may mimic the stretching effect seen in blunt trauma. There is tearing of the inelastic intima with exposure of the thrombogenic media, which becomes a nidus for embolism or for the propagation of thrombus and thrombosis. Flap or subintimal dissection by the arterial bloodstream in an area of circumferential intimal fracture may result in obstruction of the vessel or the formation of a distal thrombus. This raises the question of whether they should be treated as being thrombogenic and the patients anticoagulated as soon as possible. Unfortunately, there are no conclusive studies in this field, although recommendations have been made in accumulated overviews. Transmural traumatic arterial injuries of major vessels can result in serious delayed complications months or even years after the injury. The evaluation and management of penetrating injuries to the neck are evolving. Until the 1950s, the management of penetrating wounds to the neck was conservative and ligation was undertaken in cases of active bleeding. The result of this form of treatment was a high incidence of stroke (about 30%). The first attempts at repair were seen during the Korean conflict with some successes.

The first large civilian series in 1956, showed the benefit of direct surgical repair in comparison with simple ligation. They reported a 35% mortality in patients treated non-operatively, with a 6% mortality in those patients undergoing immediate surgical exploration. They demonstrated that the mortality rate was increased if the exploration was delayed beyond 6 h. We operated on some of our patients after a delay of 48 h. This delay, in our series, did not increase the mortality or morbidity. This landmark study establishes the original approach of mandatory exploration of all wounds penetrating the platysma. This model of management is generally accepted, with other investigators confirming the same findings. The proponents of this model report that any missed injury, even in asymptomatic patients, leads to devastating consequences.

Monson et al., in 1969, divided the neck into three zones. This let to refinement of the approach to this problem, and selective conservatism started to gain a place in the management of this type of injury. This was necessitated by the high rate of negative exploration of 60–70% and unrecognised injuries during exploration. To reduce this rate, the authors recommended angiography for injuries to Zones I an III in order to determine the need for operative intervention. For Zone II injuries, they accept the principle of
mandatory exploration, despite the high negative exploration rate of 56%.24

Refinements to angiographic techniques have resulted in many authors advocating mandatory angiography prior to surgical exploration. Most authors agree that clinical examination and ancillary investigations should replace mandatory surgical exploration in Zone I and III injuries.25 The rationale in the setting of Zone I wounds is to identify any anatomical anomalies, and to exclude injury to the thoracic outlet vessels (that may necessitate thoracotomy for proximal vascular control before the cervical tamponade is violated). The primary indication for Zone III angiography is to exclude internal carotid arterial disruption at the base of the skull. These injuries may require carotid interruption by ligation or interventional radiology (stent or embolisation).2,26,27 Naidoo et al.28 reported 41 patients with injuries to noncritical vessels treated by endovascular procedures, with very successful and encouraging results. However, we do not advocate these procedures for carotid lesions (intimal injury) for fear of precipitating embolisation of pre-existing thrombus.9 The role of concomitant extracranial–intracranial bypass remains unclear, nonoperative management has met with favorable result.29 There is little debate that those patients in an unstable condition should undergo immediate operative exploration. In our setting, active bleeding and an expanding haematoma, present reliable signs of vascular injury requiring exploration.3,21,22,25

Zone II remains the most controversial zone. This is due to easy accessibility to physical examination and ease of exploration. There are three management options advocated by varying authors: (1) Immediate exploration without prior angiography is advocated by some authors. They argue that most of the structures likely to be injured are readily accessible to the surgical field.21,22 (2) Others advocate angiography as part of the assessment and exploration is based on the angiographic findings.30 (3) Clinical assessment, with physical examination only, is recommended by some authors as a third option of selective exploration.29,31

The fact that physical examination cannot exclude arterial injuries, especially in patients with intimal injuries where hard and soft signs are absent, the use of angiography or duplex studies may prove helpful.32

Although selective conservatism for penetrating trauma to the neck is practiced in many centres,1-4,23,26 there is no consensus among authors regarding the selection criteria. Many believe that physical examination alone is safe and reliable in evaluation of patients with penetrating neck injuries2,23,30,32 Sekharan et al.2 in a prospective study and by summarising the results of two previous studies undertaken in the same Jacksonville trauma centre in Florida, indicate that physical examination alone is safe and accurate in the assessment of patients with penetrating injuries to the neck. Demetriades et al.33 found that the accuracy of physical examination is 97%, which is similar to angiography. Some injuries may be missed. However, the 3-month follow up did not reveal any significant vascular injuries. Even if there are angiographic abnormalities, less than half required surgical repair. Beitsch et al.22 found that clinically important arterial injury, in the patient with a penetrating neck wound, is rare (0.7%) and negative findings on physical examination are highly predictive of the absence of an arterial injury. Positive findings on examination are not reliably predictive of arterial injury. The addition of an erect chest X-ray to the physical examination increases the negative predictive value to 100%.34 All the above authors quote an experience of mixed stab and gunshot wounds.

Others believe that physical examination is unreliable in detecting vascular injuries. Meyer et al.,35 in a prospective study, found clinical examination to have an accuracy of only 68%. The incidence of significant vascular injuries in patients who have negative clinical finding has varied from 18% in the series by Stromberg36 to 32% in the series of Flint et al.37 In the present series 34% of patients with gunshot wounds to the neck had vascular injuries in the absence of signs on physical examination.

We believe that the assessment of patients with gunshot wounds to the neck by physical examination alone is very difficult, especially Zones I and III injuries. We recommend angiography for these injuries, even if the entrance wound is in zone II (which is accessible to physical examination), since the injury could be in the other zones.

Our results show that a high percent of injuries will be missed if reliance is placed only on physical examination. A chest X-ray adds very little to the accuracy of physical assessment.

Conclusion

Findings on physical examination are not good predictors of vascular injury in stable patients with gunshot wounds to the neck.

Our findings question the validity of physical examination alone as a safe and accurate assessment of patients with gunshot wounds to the neck. Angiography and ultrasonography are needed to identify vascular injuries.
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G. S. Mohammed et al.